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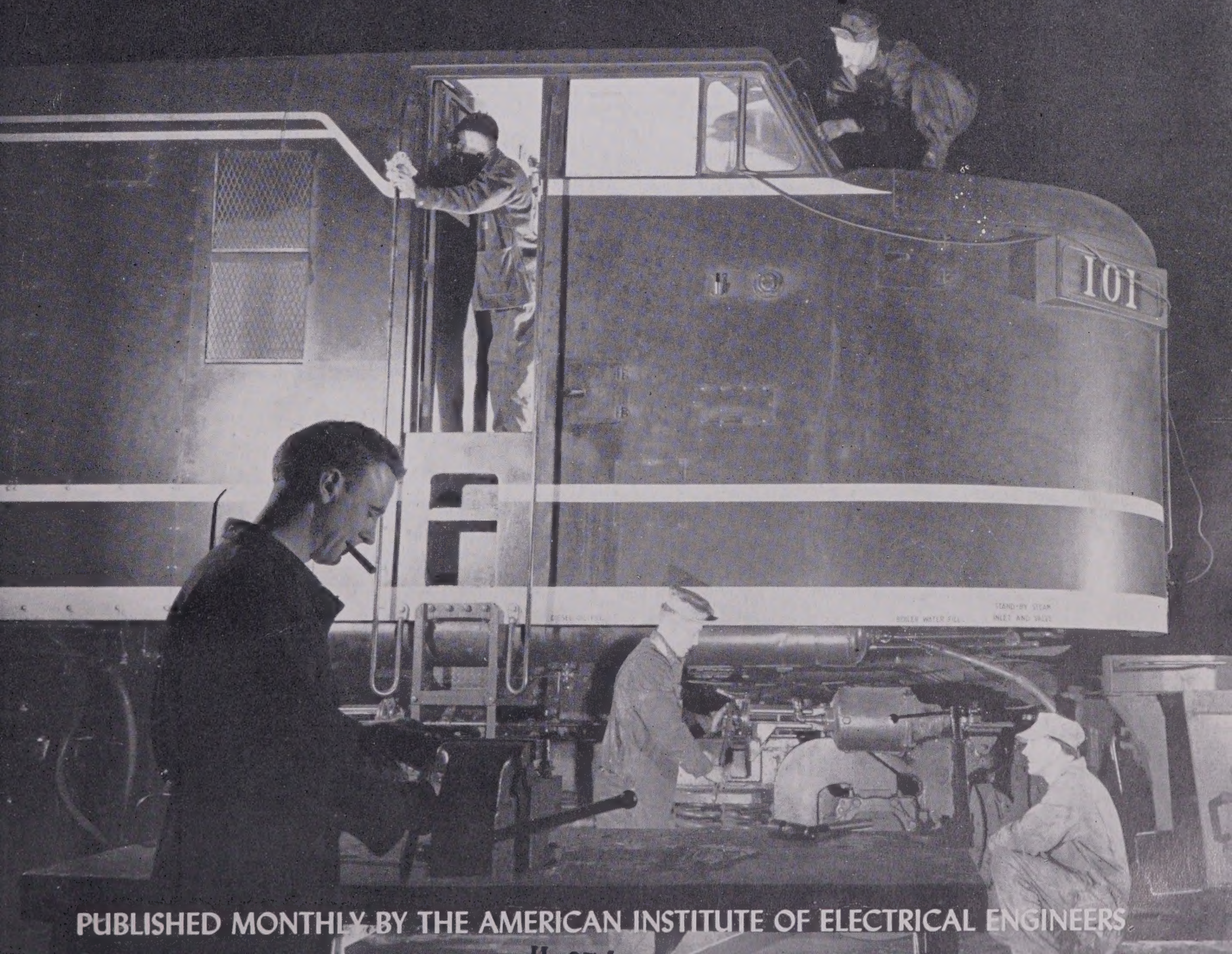

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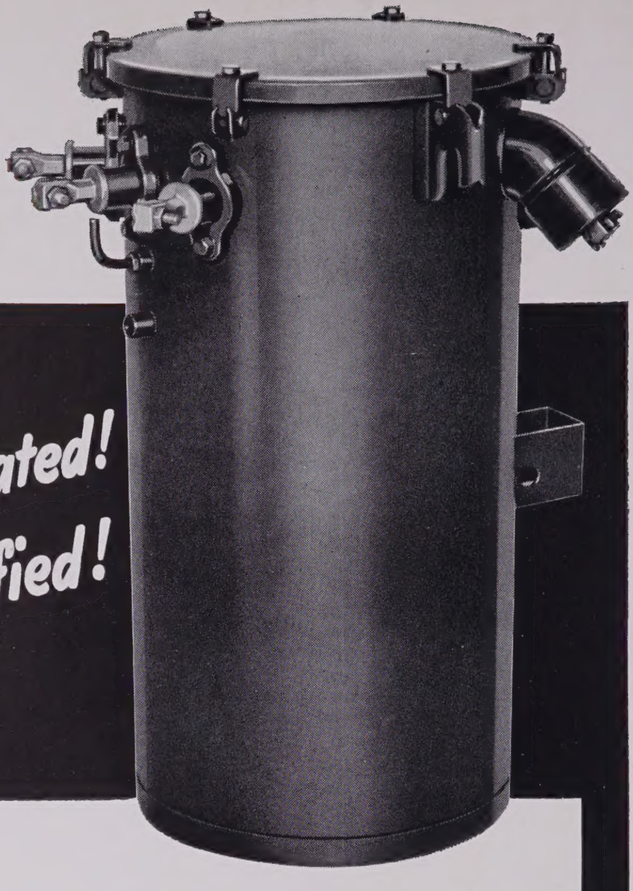

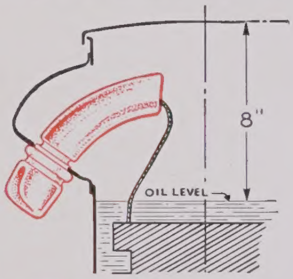

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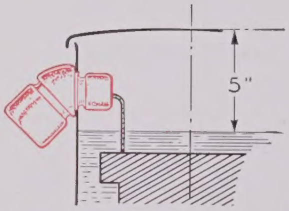

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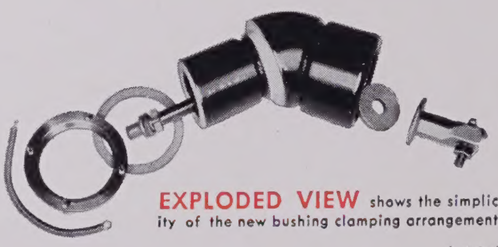

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The Cover: Checking the first gas turbine-electric locomotive to be built and operated in the United States. This 4,500-horsepower American Locomotive Company–General Electric Company unit recently completed preliminary road tests and soon will see service on the Union Pacific Railroad (see page 641).

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VOL. 68 NO. 7

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Published Monthly by the

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
Founded 1884

EVERETT S. LEE, President H. H. HENLINE, Secretary

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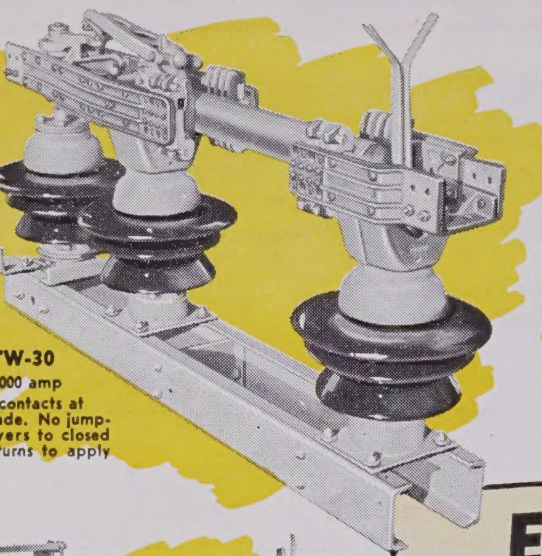

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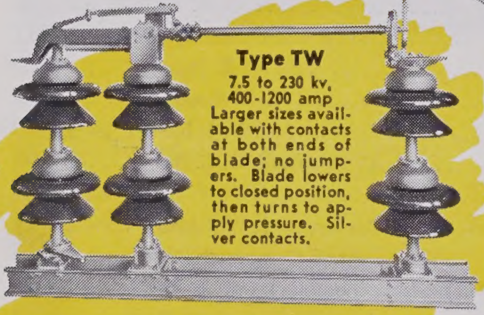

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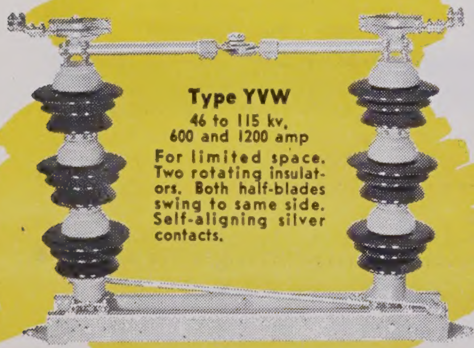

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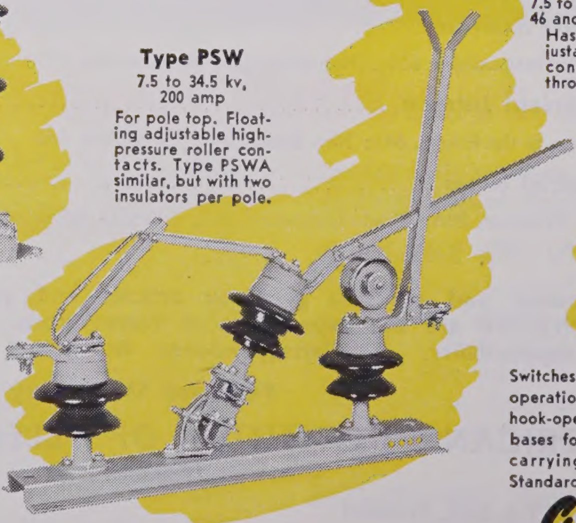

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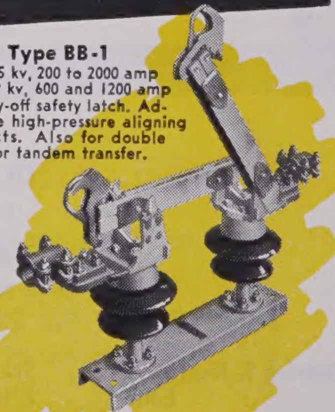

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Symbolic Nomenclature for Sinusoids

W. R. LePAGE
MEMBER AIEE

Frequently new ideas in a field are expressed inadequately in the nomenclature of prior art, whose terms may not be applicable to the new conception in certain respects; when this deficiency is realized a suitable nomenclature must be devised. In this article the author points out an example of this tendency in the present use of the term "vector" to describe the directed lines used in the treatment of sinusoidal functions and suggests that the term "sinor" be more appropriately used.

THE successful communication of ideas requires a precise definition of the descriptive words used in the discourse. Unfortunately, the requisite preciseness is sometimes lacking because the nomenclature used in a given field of thought tends to be a fluid thing, changing with the unfolding of new concepts. Sometimes new ideas are discussed in terms of old terminology which does not exactly apply, until the inadequacy is recognized and an appropriate nomenclature adopted.

A striking example of this tendency is the engineering practice of applying the term "vector" to the directed lines used in the treatment of sinusoidal functions. It is true that these lines do have certain properties of vectors, but they differ from vectors in certain important respects. This has been known since the early days of circuit analysis. In fact, in at least some of the early texts the directed lines are used without their being termed "vectors,"[1] but the use of this term seems to have rapidly become quite general. It is possible to find occasional reference to the fact that they are not vectors,[2,3] and in some cases the difference is indicated by a modification of the name to "revolving vector,"[4] "time vector,"[5] or "plane vector."[11] The interpretation of these lines as complex quantities has been appreciated since the early work of Steinmetz,[6] but the use of the term "vector" has persisted.

There appears to be some modern trend toward an acknowledgement of the error in this traditional terminology, as evidenced by the appearance of the name "phasor" in at least one recent text;[7] and in at least one published set of standard notations.[8] However, the text cited discards the innovation, and a more recent book[9] makes no mention of it at all. Both of them consistently employ the term "vector." This indicates that there is apparently no strong movement toward the adoption of a more rational nomenclature, and is taken as sufficient justification for the presentation of an objective discussion of the problem, in spite of the fact that it brings out no new information.

Probably the reason there has been no serious challenge to the established practice is that, in the past, it has done little harm. In the classical applications there is little chance for confusion with real vectors. However, with the generalization of the theory of the transient behavior of networks, and treatment of phenomena involving sinusoidally varying field quantities, this immunity has disappeared. The two types of so-called "vectors" can become well mixed, and numerous qualifying adjectives or clauses are required in such cases if the necessary distinctions are to be maintained.

The fact that the directed lines are really geometrical portrayals of complex quantities might seem to imply that a substitution of the word "complex" for "vector" is all that is needed. From one viewpoint this is perhaps true, but a critical analysis shows there is some valid argument for the adoption of a distinctive name. It is the main purpose of the subsequent discussion to present the pertinent facts in logical form. The making of a recommendation is not the prime purpose, although one is presented. The coined term "sinor" is suggested for the directed-line representation of a sinusoidal function.

THE SYMBOLIC APPROACH

By this heading is meant the intuitive (as distinct from mathematical) analysis leading to the definition of a rela-

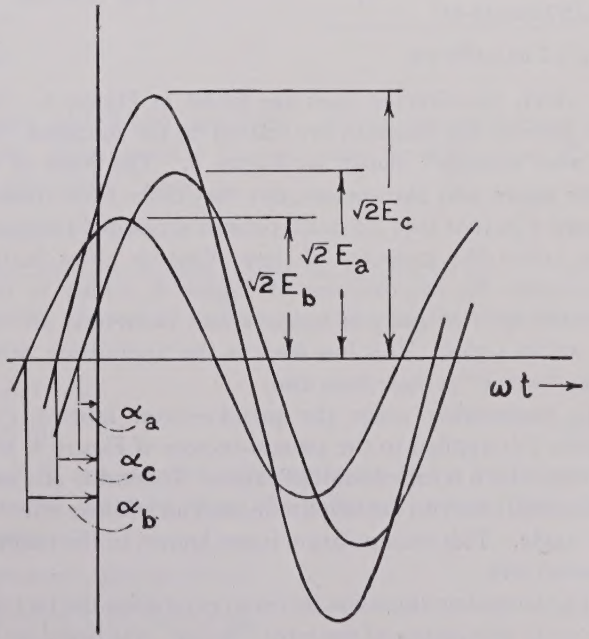

Figure 1. Combination of sinusoidal functions

Full text of paper **49-169**, "Nomenclature for the Symbolic Treatment of Sinusoids," recommended by the AIEE Basic Sciences Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Swampscott, Mass., June 20–24, 1949. Not scheduled for publication in AIEE *Transactions*.

W. R. LePage is Associate Professor of Electrical Engineering, Syracuse University, Syracuse, N. Y.

tionship between a sinusoidal function and a directed line. It is the approach customarily used in a first course in alternating currents, and is given a brief presentation in this article to permit the appraisal of its pertinent points.

The equations for the two sinusoids of Figure 1 are

$$e_a = \sqrt{2}\, E_a \sin(\omega t + \alpha_a) \tag{1a}$$

$$e_b = \sqrt{2}\, E_b \sin(\omega t + \alpha_b) \tag{1b}$$

and they are represented by the directed lines of Figure 2. This is a useful representation because the vector sum of the original lines is itself a line, which represents, in the same way, the sinusoid

$$e_a + e_b = e_c = \sqrt{2}\, E_c \sin(\omega t + \alpha_c) \tag{2}$$

The significant point is the appearance of the word "vector" in the foregoing sentence, where it is correctly employed. These directed lines add like vectors, but this is their only similarity, and it does not mean that the lines are vectors. Vectors are mathematical quantities which have various laws of manipulation, other than addition, which do not agree with those used on the directed lines of Figure 2.

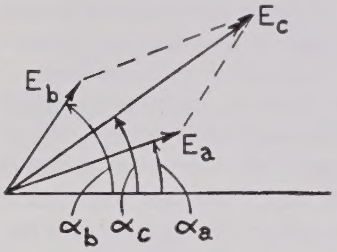

Figure 2. Directed-line representation for sinusoids, showing that they may be added like vectors

The concept of a pseudo-vector enters into the a-c theory in a second way. It is illustrated by the simple series circuit of Figure 3. From basic principles, the current and potential can be written as

$$i = \sqrt{2}\, I \sin(\omega t + \beta) \tag{3a}$$

$$e = \sqrt{2}\, E \sin(\omega t + \beta + \theta) \tag{3b}$$

for which the directed lines are found in Figure 4. The two lines of this diagram are related by the so-called "impedance triangle" shown in Figure 5. The lines of the latter figure add like vectors, but they differ from those of Figure 4 in that they do not represent sinusoidal functions. The vector-like property of these lines is given further illustration by the diagram of Figure 6, which is constructed for two pairs of resistors and inductors, all connected in series. This has lead to the application of the term "vector" to these lines also.

In engineering usage the pseudo-vector labeled $\mathcal{Z}$ in Figure 5 is applied to the pseudo-vectors of Figure 4, by a process which is called multiplication. It consists of a multiplication effect on the amplitude, and an additive effect on the angle. This manipulation is not known in the realm of true vectors.

The foregoing discussion serves to emphasize the fact that the early acceptance of the term "vector" was based on the addition property alone, and that it is mathematically improper. The discussion presents the essential aspects of the technique of applying directed lines to the solution of a-c problems. The concept of the "operator" $j = \sqrt{-1}$ was purposely omitted because it is largely incidental to this approach.

The two distinct uses for directed lines have been emphasized. From the physical viewpoint they are significantly different. One type of line, as used in Figures 2 and 4, is a symbolic representation for a sinusoidal time function. The other type of line, as used for the impedance triangle, is related to a sinusoid in an entirely different way. It is used in the sense of an operator, to change the magnitude and direction of one of the sinusoid-representing lines. The lines of Figures 5 and 6 do not represent sinusoids at all, but they do represent operations on sinusoids.

THE MATHEMATICAL APPROACH

The mathematical meaning of the symbolic representations discussed in the foregoing is bound up in the identity of Euler

$$A\epsilon^{jx} = A(\cos x + j \sin x) \tag{4}$$

and the relations

$$\operatorname{Im}(A\epsilon^{jx} + B\epsilon^{jy}) = \operatorname{Im}(A\epsilon^{jx}) + \operatorname{Im}(B\epsilon^{jy}) \tag{5a}$$

$$\frac{d(\operatorname{Im}(A\epsilon^{jx}))}{dt} = \operatorname{Im}\left(\frac{d(A\epsilon^{jx})}{dt}\right) \tag{5b}$$

In these equations A, B, x, and y are real functions of some independent variable t, and the symbol Im (—) means the imaginary part of (—).

The example of the directed lines of Figure 2 is considered by writing equation 1 in the form

$$e_a = \sqrt{2}E_a \sin(\omega t + \alpha_a) = \operatorname{Im}(\sqrt{2}E_a\epsilon^{j(\omega t + \alpha a)}) = \operatorname{Im}(\sqrt{2}E_a\epsilon^{j\alpha_a}\epsilon^{j\omega t}) \tag{6a}$$

$$e_b = \sqrt{2}E_b \sin(\omega t + \alpha_b) = \operatorname{Im}(\sqrt{2}E_b\epsilon^{j(\omega t + \alpha_b)}) = \operatorname{Im}(\sqrt{2}E_b\epsilon^{j\alpha_b}\epsilon^{j\omega t}) \tag{6b}$$

These follow from equation 4. With the inclusion of equation 5*a* there follows

$$e_a + e_b = e_c = \operatorname{Im}[(\sqrt{2}E_a\epsilon^{j\alpha_a} + \sqrt{2}E_b\epsilon^{j\alpha_b})\epsilon^{j\omega t}] \tag{7}$$

When the complex numbers $E_a\epsilon^{j\alpha_a}$ and $E_b\epsilon^{j\alpha_b}$ are plotted in the conventional manner they are identical with the directed lines of Figure 2. Hence, these directed lines really may be treated as complex numbers.

These facts imply that there is a useful correspondence between complex constants and sinusoidal functions of time, which may be suggested by the symbolism

$$E_a\epsilon^{j\alpha_a} \text{ represents } \sqrt{2}E_a \sin(\omega t + \alpha_a) \tag{8a}$$

$$E_b\epsilon^{j\alpha_b} \text{ represents } \sqrt{2}E_b \sin(\omega t + \alpha_b) \tag{8b}$$

The complex number represents the entire sinusoid, in a symbolic way. There has been no standardization as to

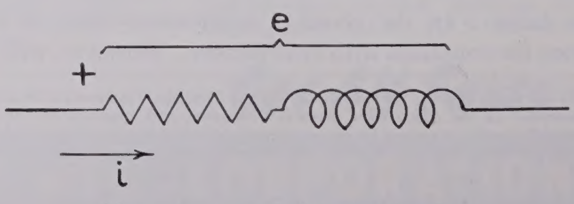

Figure 3. A typical series circuit

whether this representation shall be based on the sine or the cosine function. It is suggested that a standardization of this would be valuable, and that it would not be unduly restrictive. The sine form is suggested.

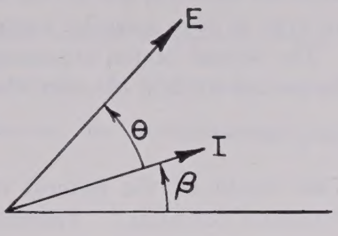

Figure 4. Directed-line representation for the typical impedance operator

When circuit elements are involved this approach leads to the interpretation of a complex impedance. For the circuit of Figure 3 let the current be given by

$$i = \mathrm{Im}(\sqrt{2} I \epsilon^{j\beta} \epsilon^{j\omega t}) \tag{9}$$

which means

$$I\epsilon^{j\beta} \text{ represents } \sqrt{2} I \sin(\omega t + \beta) \tag{10}$$

From the differential equation of the circuit

$$e = R\,\mathrm{Im}(\sqrt{2} I \epsilon^{j\beta} \epsilon^{j\omega t}) + L \frac{d(\mathrm{Im}(\sqrt{2} I \epsilon^{j\beta} \epsilon^{j\omega t}))}{dt} \tag{11}$$

When identities 5*a* and 5*b* are brought to bear on this it becomes

$$e = \mathrm{Im}(\sqrt{2} I \epsilon^{j\beta} (R + j\omega L) \epsilon^{j\omega t}) \tag{12a}$$

$$e = \mathrm{Im}(\sqrt{2} I \epsilon^{j\beta} Z \epsilon^{j\theta} \epsilon^{j\omega t}) \tag{12b}$$

$$e = \mathrm{Im}(\sqrt{2} I Z \epsilon^{j(\beta + \theta)} \epsilon^{j\omega t}) \tag{12c}$$

where $Z\epsilon^{j\theta} = R + jX$ is the complex representation of the impedance. When plotted in the conventional manner it is identical with the diagram of Figure 5. Thus, the directed lines which represent impedances are complex quantities. Equation 12*c* is equivalent to the relation

$$IZ\epsilon^{j(\beta+\theta)} \text{ represents } \sqrt{2} IZ \sin(\omega t + \beta + \theta) \tag{13}$$

which completes the expression of similarity with the symbolic approach.

Emphasis in the mathematical interpretation is to be placed on the multiplication which appears within the parentheses of equation 12*b*. The complex numbers $I\epsilon^{j\beta}$ and $Z\epsilon^{j\theta}$ are multiplied together, to give $IZ\epsilon^{j(\beta+\theta)}$, in accordance with the established rules for multiplying complex numbers.

POSSIBLE AMBIGUITIES

The differences between complex numbers and vectors have been touched upon. One of the basic reasons for the desirability of separating them clearly lies in the difference in their laws of multiplication. In addition to this, as was mentioned in the introduction, there are two types of problem in which there is possibility of confusion if a clear distinction is not made. One problem arises with the use of true vectors to represent the transient response of a lumped network. However, this will be passed over without further comment because of the length to which an adequate discussion would have to be carried.[10] The other possible source of confusion involves sinusoidally varying space vectors. Two examples of this will serve as illustrations.

1. *Flux Distribution in a Rotating Machine.* The theory of a-c machines employs the concept of various space-sinusoidal components of flux density. The theory uses directed lines to represent these sinusoidally distributed components, and combines them by vector addition. Usually the concept is applied to the time-varying flux linking a coil, but it is equivalent to the combination of the space-distributed components specified in the foregoing. The relation of the latter to the actual vector relations in the field is not always made clear. Under all conditions the flux densities are vector functions of time and space, and may be added vectorially at a given point and instant. However, when applicable, the pseudo-vector combination applies to the entire distribution. There should be less confusion between these two processes if the term "vector" were not applied to both.

2. *Electric Field in a Plane Wave of Radiation.* This is a simple example of the possible mixture of complex and vector quantities that can occur in field problems. Let a plane wave of elliptic polarization be propagated along the *z* axis of a rectangular system. A complex quantity is indicated by a dash above its symbol, and a vector quantity by heavy-type characters. At a point in space the field is explicitly represented by the equation

$$\boldsymbol{E} = \sqrt{2}[k_x E_x \,\mathrm{Im}(\epsilon^{j\alpha_x} \epsilon^{j\omega t}) + k_y E_y \,\mathrm{Im}(\epsilon^{j\alpha_y} \epsilon^{j\omega t})] \tag{14}$$

in which k_x and k_y are unitary vectors in the respective *x* and *y* directions. An interpretation of this equation in two ways serves to emphasize the difference between complex and vector quantities. A symbolic representation for the above explicit function may be defined as $\bar{\boldsymbol{E}}$, a complex vector, where

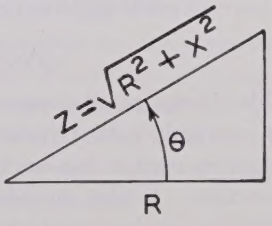

Figure 5. The directed-line representations for current and potential, as related to the impedance diagram

$$\bar{\boldsymbol{E}} = k_x E_x \epsilon^{j\alpha_x} + k_y E_y \epsilon^{j\alpha_y} \tag{15a}$$

$$\bar{\boldsymbol{E}} = (k_x E_x \cos \alpha_x + k_y E_y \cos \alpha_y) + j(k_x E_x \sin \alpha_x + k_y E_y \sin \alpha_y) \tag{15b}$$

Equation 15 can be written in either of the abbreviated forms

$$\bar{\boldsymbol{E}} = k_x \bar{E}_x + k_y \bar{E}_y \tag{16a}$$

$$\bar{\boldsymbol{E}} = \boldsymbol{E}_1 + j\boldsymbol{E}_2 \tag{16b}$$

$\bar{E}_x$ and $\bar{E}_y$ are complex representations of the vector components of the field along the reference axes. They are interpreted as

$$\bar{E}_x \text{ represents } \sqrt{2} E_x \sin(\omega t + \alpha_x) \tag{17a}$$

$$\bar{E}_y \text{ represents } \sqrt{2} E_y \sin(\omega t + \alpha_y) \tag{17b}$$

The components $\boldsymbol{E}_1$ and $\boldsymbol{E}_2$ of equation 16*b* have an entirely different significance. They are not directed along the coordinate axes, but are directed at angles which are functions of the constituents of equation 15*b*. It is not necessary to know these angles for the present discussion. In these directions the two components of equation 16*b* have the meanings

$$|\boldsymbol{E}_1| \text{ represents} \sqrt{2(E_x\cos\alpha_x)^2+2(E_y\cos\alpha_y)^2}\,\sin(\omega t) \qquad \textbf{(18a)}$$

$$j|\boldsymbol{E}_2| \text{ represents} \sqrt{2(E_x\sin\alpha_x)^2+2(E_y\sin\alpha_y)^2}\,\sin\left(\omega t+\frac{\pi}{2}\right) \qquad \textbf{(18b)}$$

A comparison of these two interpretations should serve to emphasize the basic difference between the two types of quantity. This problem also emphasizes the importance of keeping in mind the relationship between the complex-number representation of a sinusoid and the sinusoidal time function which it represents. In the analysis of lumped networks there is usually little need to revert to the sinusoidal function, and relationships such as equation 8 seldom are needed. However, the vector components of the field cannot be combined unless the complex parts of the expression for the field are reduced to the appropriate time functions. Equations 16 are entirely symbolic, and must be interpreted in terms of either equations 17 or 18 to have physical significance.

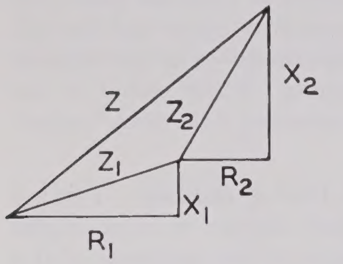

Figure 6. Illustration of the combination of operator diagrams by vector addition

CONCLUSIONS

The foregoing discussions serve to review the source of the currently-used terminology, and the relation of the quantities used in a-c work to the mathematics of complex quantities. It also includes a brief review of some of the conditions under which there is a possibility of confusion when the term "vector" is applied to the symbolic treatment of a sinusoidal function.

The present discussion is based on the fact that the directed-line representation of a sinusoidal function is a complex number, and not a vector. There is justification therefore in asking why it is not sufficient to merely substitute the word "complex," or "complex number," for "vector."

In the realm of real numbers there would be much precedent for doing this. All quantities which are represented by real numbers share the real-number system without the need for special designatory names. When a variable is plotted on a graph, as in the plot of instantaneous values of potential, the ordinates are looked upon merely as real numbers. No special designation is used to qualify them as special numbers because they represent a potential.

There are perhaps two foundations for the argument that the directed lines used in a-c analyses require special names. These are the following: (*a*) the possibility of deriving most of the useful properties of these lines without recourse to the mathematics of complex numbers; and (*b*) the fact that the complex number which represents a sinusoidal potential does not do so directly.

The weight of the first of these arguments is obvious from the earlier discussions. The name "vector" fitted the situation naturally for a long time, and if it is lost there is an urge to have a similar name to replace it.

The second of the arguments bears some clarification. As an aid to this, consider the quantity $\bar{e}$, written as

$$\bar{e}=\sqrt{2}E\epsilon^{j(\omega t+\alpha)} \qquad \textbf{(19)}$$

This would be the natural recipient of the designation "complex potential." Therefore, the quantity

$$\bar{E}=E\epsilon^{j\alpha} \qquad \textbf{(20)}$$

would not carry the same name if both functions are ever to be considered simultaneously. The discussion here, of course, is based only on what might be considered a reasonable approach, and it does not absolutely preclude the use of the term "complex potential" for equation 20.

Continuing to assume that a new name is desirable, the phrase "complex representation of a potential" would be acceptable except for its length. In its stead is suggested the name "sinor potential" or "potential sinor." The coined word "sinor" is intended to convey the thought "representer of a sine wave." The directed lines used for currents and potentials, or any sinusoidally varying scalar quantity, would then be called sinors instead of vectors.

This suggestion makes no provision for the complex quantities which represent impedances and other operators of similar characteristics. It is believed that these are adequately described by the term "complex." In view of the difference in meaning of the directed-line representations of sinusoids and operators, as discussed in the foregoing section on "The Symbolic Approach," it is not illogical to have a characteristic name which applies only to the sinusoidal representations.

Against the possible argument that it is confusing to use two names for a complex quantity, depending on the use to which it is put, it is pointed out that there is pedagogical value in making the distinction. It serves to point out the basic difference in their meaning.

Whether or not the name "sinor" is preferable to any other will not be decided by such a discussion as this. Its main tenor is to emphasize the need for such a name, and to point out that if the name "complex" is not used for all the directed lines, the new name should apply only to those that represent sinusoids.

One other suggestion is made, to the effect that there should be defined a definite relationship between a sinusoidal function and its complex representation. There is probably not much divergence in the actual practice of this, but it is felt that the invention of a symbol to indicate the relationship would be of value. Such a symbol as $\triangleq$, for example, could be used to replace the word "represents" as it has been used in many of the foregoing relations, so that the symbolism could be indicated by

$$E\epsilon^{j\alpha} \triangleq \sqrt{2}E\sin(\omega t+\alpha) \qquad \textbf{(21)}$$

This possibly would broaden the meaning of the complex-number (or directed line) representation. It also could facilitate transfers in either direction between time functions and their directed-line equivalents.

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1949 Employment Programs for Engineering Graduates

In an effort to secure some indication of 1949 employment programs for engineering graduates, an Engineers Joint Council committee recently concluded a survey of representative industrial companies and governmental agencies. Of 500 questionnaires sent out late in January, about 190 had been returned by the latter part of March and are included in the preliminary tabulation of results now released.

THE GENERAL Survey Committee of the Engineers Joint Council recently conducted a spot survey of industrial companies and governmental agencies concerning their 1949 employment programs for engineering graduates. This committee was set up last summer by the council, which is made up of representatives of the major engineering societies, to act as a central fact-gathering agency to secure reliable information concerning trends within the engineering profession.

The questionnaire, prepared for use in this first survey undertaken by the committee, was sent late in January to about 500 carefully selected industrial and governmental organizations. The results presented here are based on about 190 returns received by the middle of March. Additional returns still are coming in and will be incorporated in the final report to be published as soon as practicable in an appropriate journal.

This survey sought to cover the following points:

1. The relative demand for inexperienced engineering graduates in 1948 and 1949.

2. The 1949 starting salaries for such graduates with bachelors', masters', or doctors' degrees, together with related information on differentials by curricula or geographical area, credits for military service, and increases during the first year of employment.

3. The trend of salaries for engineering graduates ten years out of college since the 1946 survey of the Engineers Joint Council reported in the volume "The Engineer in Transition," as merely an indication of the salary trend for such graduates of some maturity.

To assist in evaluating the data secured, related information concerning the total number of employees in the organization, and the number of engineering graduates was requested also.

RELATIVE 1948 AND 1949 DEMAND

Table I presents the latter information for the organizations responding by industrial and governmental groups, together with data concerning their 1948 and estimated 1949 employment of engineering graduates.

Although the organizations represented by Table I include only about one-eighth of the total employees in the manufacturing, mining, construction, public utility, and transportation industries, and in governmental agencies, they have more than one-quarter of the approximately 265,000 engineering graduates in the United States.

Even though 9,800 inexperienced graduates employed in 1948 presumably included some men who were graduated before that year, they represent a somewhat similar proportion of such graduates who then became available for employment. Although these organizations obviously represent a widely varying proportion of their industries, it may be concluded that they constitute a significant and reasonably reliable sample of the total employment market for these graduates. While the decreased demand indi-

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Full text of a progress report issued by the General Survey Committee of the Engineers Joint Council.

Table I. Employment of Engineering Graduates by Industrial and Governmental Groups

			Engineering Graduates			
				Inexperienced		
Employing Organizations	Number of Organizations	Total Employees	Total in Companies	Hired 1948	Quotas 1949	Per Cent Change
Industrial						
Aircraft	4	53,500	1,850	345	115	−66.5
Automotive	6	602,200	3,495	393	445	+11.3
Building materials	8	24,948	1,278	141	92	−34.7
Chemical	11	147,212	5,480	526	476	− 9.5
Consulting	4	3,631	692	58	31	−46.5
Construction	4	18,967	1,486	88	52	−40.9
Electrical	8	429,396	18,189	2,101	1,376	−34.5
Food	9	120,501	697	72	76	+ 5.3
Glass	3	29,700	451	36	39	+ 8.3
Instruments	8	25,016	1,413	152	96	−36.6
Machinery	20	236,726	3,470	355	332	− 6.5
Metals	14	264,158	3,393	458	423	− 7.6
Paper	7	28,278	404	86	67	−24.4
Petroleum	10	195,453	5,152	969	627	−35.3
Public utility	21	673,545	9,889	919	579	−37.0
Rubber	6	183,730	3,620	404	303	−25.0
Shipbuilding	2	5,000	50	5	17	*
Soap	2	20,500	870	156	151	− 3.2
Textiles	5	34,200	195	36	36	0.0
Transportation	3	274,000	1,914	93	107	+15.1
Total industrial	155	3,370,661	63,988	7,393	5,440	−26.4
Governmental						
Federal Government	8	77,531	6,964	1,639	1,046	−36.3
State Government	19	118,840	4,767	764	1,075	+40.7
Total governmental	27	195,371	11,731	2,303	2,121	− 7.9
Grand total	182	3,567,032	75,719	9,796	7,561	−22.8

* Not significant.

cated for 1949 undoubtedly has been influenced by the recent decline in business activity, it is probable that the filling of shortages accumulated during and immediately after the war has been a large factor.

Table II indicates by type of engineering training the number of graduates sought in 1949 by the responding organizations as estimated from the percentage distributions given in their replies.

Table II. 1949 Quotas of Inexperienced Engineering Graduates by Principal Curricula

Chemical and ceramic	993
Civil and structural	1,966
Electrical	1,757
Mechanical, aeronautical, and industrial	2,425
Mining	181
Other	239
Total	7,561

STARTING RATES

Examination of the data concerning starting rates revealed that very few companies paid different rates to graduates of different engineering curricula and only a limited number used geographical differentials. There were, however, significant variations between the rates paid by organizations employing primarily chemical engineers and, to a lesser extent, mechanical engineers, as compared with those paid by organizations employing mainly electrical or civil engineers. The significant factor, in other words, appeared to be the market rate which applied to the major type of engineers sought by a company. Table III, therefore, is set up on that basis. The numbers shown are slightly larger than in the early tables since two or three small companies provided starting rate figures only. They include those for whom postgraduate training may be desired.

Table IV gives median starting rates for men with bachelors', masters', and doctors' degrees. Since, however, the number of men with advanced degrees to be employed was not requested, it has been compiled from the rates paid by each company providing data regardless of size. The median rates it gives for bachelors' degrees, therefore, differ somewhat from those of Table III. These differences indicate whether the larger organizations tend to pay the higher rates as in the case of those employing mainly chemical engineers and mechanical engineers or whether the smaller organizations tend to do so, as in that of civil engineers.

Cost of living allowances used by a number of oil companies and a few other organizations have been included in these figures. The use of any other type of allowance was negligible.

In tabulating these rates, the mid-points of the range of rates used by certain organizations were taken unless other evidence indicated that a different point in the range was normally employed. Although as already stated, practically no companies had established differentials by curricula, it is probable that some which gave ranges, ordinarily used higher points within them for graduates of certain curricula as compared with others.

As already mentioned, few organizations (11 in fact) indicated that they had set up geographical differentials in their starting rates and even in these cases the pattern varied in accordance with the location of their head-

Table III. Monthly Base Starting Rates Engineering Graduates With Bachelors' Degrees by Principal Curricula Used in Employing Organizations

Principal Curricula	1949 Quotas	Median[a] Upper Half	Median[b] Whole Group	Median[c] Lower Half
Chemical or ceramic	1,449	300	290	270
Civil or structural	2,129	270	250[d]	250[d]
Electrical	2,098	255	250	245
Mechanical, aeronautical, or industrial	1,862	275[d]	275[d]	255
Other	83	250[d]	250[d]	250[d]
Toal	7,621	275	255	250

(a). Exceeded (or equaled) by 25 per cent of cases.
(b). Exceeded (or equaled) by 50 per cent of cases.
(c). Exceeded (or equaled) by 75 per cent of cases.
(d). Identical, due to heavy concentration of cases at this rate.

Table IV. Monthly Starting Rates Medians by Educational Levels

Principal Curricula	Bachelors Number*	Bachelors Rate	Masters Number*	Masters Rate	Doctors Number*	Doctors Rate
Chemical or ceramic	38	$275	34	$315	29	$400
Civil or structural	30	260	17	275	7	295
Electrical	36	250	21	280	8	375
Mechanical, aeronautical, or industrial	76	255	43	295	25	350
Other	6	250	1	310	1	375
Total	187	260	116	300	70	375

* Of organizations reporting.

quarters and character of their work. The most usual differential was for assignment to the West Coast and varied in amount from $15 to $35 per month. In two or three instances, a somewhat smaller differential was paid for New York City and in a similar number of others, lower salary rates were paid for the South and West Central areas.

No more definite geographical pattern is found through tabulation of the starting rates by the locations of the headquarters of the reporting organizations. With one exception, the variations which are revealed, seem clearly due to the character of the organizations concentrated in particular areas rather than to geographical factors. That exception again is on the Pacific Coast where a median rate of $300 independent of such influences. The total number of positions reported by companies with headquarters in that area, however, is only 235.

Tabulation of starting rates by industrial and governmental groups does bring out some significant differences and makes it clear that the differing market rates for graduates of the several curricula are greatly influenced by the industries seeking men from those curricula. Table V presents the medians for those groups which contain a number of organizations employing a substantial total number of graduates.

Tabulation of these rates for industrial companies by size of organization indicates that somewhat lower rates (median $250) are paid by companies with fewer than 5,000 employees. For the larger companies, although some variations occur, they seem to be determined primarily not by company size but by the industry and curriculum from which they are seeking graduates.

Fifty of the 183 organizations returning questionnaires reported that they gave a differential for military service. In 29 of these cases, its amount was stated as based on the value of the individual's military experience to the organization and in 13 cases, it was based on "individual consideration," a very similar criterion. In the remaining cases, other reasons, such as length of time spent in military service, was the determining factor. Companies employing mainly chemical or electrical engineers were most likely to pay such differentials; those employing mainly mechanical engineers seemed least likely to do so. The proportion of the companies with more than 10,000 employees paying this differential was about double that of the smaller companies and a somewhat higher proportion of the private companies than of the governmental organizations reported that they did so.

VI. Salary Increases During First Year of Employment by Principal Curriculum Used

Principal Curriculum	Number of Organizations	Number of Increases[a] 1	Number of Increases[a] 2	Number of Increases[a] 3 or 4	Automatic	Merit	Medians (Per Month)[b] Top Half	Medians (Per Month)[b] All	Medians (Per Month)[b] Lower Half
		(Percentage of Totals)					(Totals for Year)		
Chemical or ceramic	36	43.7	56.3	0.0	23.4	76.6	$40	$25	$25
Civil or structural	28	68.0	27.3	4.7	46.4	53.6	30	18	10
Electrical	36	32.3	50.0	17.7	44.5	55.5	45	33	25
Mechanical, aeronautical, or industrial	73	37.2	56.6	6.2	35.5	64.5	45	30	25
Other	5	25.0	75.0	0.0	0.0	100.0		45	
Total	178	41.5	51.6	6.9	36.6	63.4	45	30	20

(a). Excluding 19 companies determining intervals on individual basis.
(b). Excluding 18 companies determining amounts on individual basis.

Table VI presents data concerning the practices of the responding organizations with regard to increases during the first year of employment. The data are given by organizations with no attempt to weight them for the number of graduates hired. No analyses by industry, size of organization, or region, moreover, were undertaken. A few organizations did not provide this information in their responses.

Table V. Monthly Starting Rates Engineering Graduates with Bachelors' Degrees by Industrial and Governmental Groups

Employing Organizations	Number of Organizations	1949 Quotas	Median Rates
Industrial			
Automotive	6	445	$275
Chemical	12	484	290
Electrical	8	1,376	245
Machinery	20	332	245
Metals	14	423	260
Petroleum	10	627	300
Public utilities	21	579	260
Rubber	6	303	270
Total Industrial*	159	5,500	260
Governmental			
Federal	8	1,046	250
State	19	1,075	250

* Including other industries not listed.

The final item concerning starting rates covered those paid to graduates in business administration and liberal arts as compared to engineering. Table VII set up by organization only without regard to numbers of men hired presents data on this point. The relative numbers of organizations shown indicate the extent to which organizations seeking engineering graduates employ enough business graduates or arts graduates to be able to establish a rate for them.

These figures indicate relatively uniform rates for the business and arts graduates, particularly at the bachelors' level. The greatest differences between such graduates and those in engineering, therefore, are shown for organizations which pay the higher rates for the latter. As a matter of fact, of all reporting organizations, about one-half pay the same rates to bachelors in business and arts as to those in engineering, one-half pay lower rates, and practically none pay higher rates. At the masters' level, about two-thirds of the organizations pay the same rates to the nonengineers and one-third pay lower rates. Organizations employing mainly electrical engineers, generally pay the same rates and those employing mainly chemical engineers in most instances pay lower rates for the nontechnical men employed.

Table VII. Monthly Median Salaries for Engineering, Business, and Arts Graduates by Principal Engineering Curriculum Used

Principal Engineering Curriculum	Number of Organizations Reporting: Engineering	Business	Arts	Medians: Engineering	Business	Arts
Bachelors' Degrees						
Chemical and ceramic	38	29	25	$275	$250	$250
Civil and structural	30	13	7	260	235	235
Electrical	36	22	17	250	250	250
Mechanical, aeronautical, and industrial	76	45	35	255	250	250
Other	6	4	4	250	240	240
Totals	187	113	88	260	250	250
Masters' Degrees						
Chemical and ceramic	34	17	16	315	300	290
Civil and structural	17	7	5	275	275	275
Electrical	21	11	7	280	285	275
Mechanical, aeronautical, and industrial	43	19	15	295	275	260
Other	1	2	2	310	280	250
Totals	116	56	45	300	275	275

SALARIES OF GRADUATES TEN YEARS OUT OF COLLEGE

In recognition of the fact that many organizations would not have data concerning the salaries of graduates with several years of experience in their organizations readily available, the questionnaire sent out requested current information of this sort only for men ten years beyond their bachelors' degrees and made it possible to present such data either as an estimate or as the result of a definite compilation. In addition, comparable data were requested for the fall of 1946 in order that the current figures might be related to those reported in the volume, "The Engineer in Transition." In wording the questions, special care was taken to insure that the men considered represented those men who were ten years beyond their bachelors' degrees in each year.

Table VIII. Monthly Salaries Engineering Graduates Ten Years After Bachelor's Degree by Principal Curriculum Used by Employing Organization

Principal Curriculum	Number of Organizations	Number of Graduates	Median Upper Half	Median Whole Group	Median Lower Half
Chemical or ceramic	18	407	550	520	450
Civil or structural	13	235	450	400	385
Electrical	20	506	435	400	400
Mechanical, aeronautical, or industrial	31	283	550	500	450
Total	82	1,431	510	450	400

Eighty-two of the 187 organizations furnishing starting rates provided data on this point, 44 of them based on definite compilations, 38 as estimates. The resulting figures, however, varied only slightly for the two groups and it seems reasonable to present combined totals without serious question concerning their reliability. These are given in Table VIII, which is set up on the basis of the principal curriculum from which the employing organization now seeks its engineering graduates. In general, that corresponds closely with the one from which these men of ten years standing have been drawn despite a few shifts in individual companies.

Analyses of these data by specific industries, size of organization, or geographical area gave results which seem reliable only in one or two groups in each series, or are heavily weighted by a single organization. Comparisons on these bases, therefore, appear likely to be misleading and, accordingly, such comparisons are not presented in this report.

Table IX presents the comparative data secured by this survey for 1948 and 1946 and the corresponding 1946 data presented in "The Engineer in Transition." No specific table in that publication exactly paralleled the current figures but an extremely close approximation has been made through combining tables which the publication contained.

Table IX. Monthly Salaries Engineering Graduates Ten Years After Bachelor's Degree

	Number of Cases	Median Upper Half	Median Whole Group	Median Lower Half
Present Survey				
1948	1,431	510	450	400
1946	1,511	430	375	360
"Engineer in Transition"				
1946	1,085*	465	395	335

* One-third of 2,667 graduates in private employment and 559 in public employment (total 3,256) with 9–11 years of professional experience.

It is interesting to note that the current survey covers more cases of this degree of maturity than the earlier one. The latter, however, using individual returns, undoubtedly covered a wider range of employers and this fact presumably is reflected in the greater spread of salaries within the middle half of the groups. The moderate difference in the medians of those groups as a whole may be due either to chance factors or to the fact that the earlier questionnaire went only to members of the engineering societies whose salaries are likely to be somewhat above those of all graduates. In any case, the general level of such salaries for men ten years out in 1946 seems rather well established and the 1948 figures from the current survey would seem reasonably reliable.

Die-Cast Rotors for Induction Motors

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DIE-CAST rotors for induction motors have been manufactured for ratings from about 1/200 to 50 horsepower for approximately 25 years, and more recently rotors have been die-cast for the larger ratings through 125 horsepower. They have many advantages to both the manufacturer and customer. The die-cast rotor is a solid and fairly homogeneous mass that retains its balance, and in general, gives the customer good all-around performance. The manufacturer generally can make die-cast rotors at a lower cost which is to the advantage of both the customer and manufacturer. Since World War II, aluminum, which is used in die-cast rotors, has been more plentiful than copper and at a lower cost, thus making it easier for the manufacturer to maintain his production.

There are two common methods of die-casting rotors, namely, the closed-mold or high-pressure type and the end-mold or "dunking" type. In the end-mold or "dunking" method, for small rotors, the stack of laminations is assembled onto an arbor with a head on one end, or fastened to one end-ring mold. There is a spiralled key on the arbor to skew the laminations, which cannot move when once assembled. End-ring molds are assembled to each end of the stack of laminations and the whole assembly tightened by a nut on the arbor. Unless properly controlled by using a torque indicator or torque wrench when tightening the nut, there may be excessive pressure exerted between laminations which will increase the eddy-current losses. The normal frequency loss would not amount to very much but there can be considerable loss at tooth pulsation frequencies. The assembled unit then is placed into a well into which hot metal has been poured. The metal is forced under pressure through the ports in the lower ring mold, then into the slots and upper end-ring mold. Ports in the upper mold permit the air and gases to pass through them.

There are many problems that must be solved, prior to the production of new designs, that require close co-operation between the designers and manufacturing organization. The eddy-current and hysteresis losses at fundamental and tooth pulsation frequencies will be increased in die-cast rotors if the laminations and rotor slots are not properly insulated prior to die-casting. If there is no insulation, the cast metal will short-circuit the laminations, thus increasing the eddy-current losses. The conductors also will be short-circuited within the slots, thus setting up a network of paths for circulating currents. Excessive pressure on the laminations during the casting operation, and excessive burrs due to punching also will increase the eddy-current losses. Punching strains and bending of the laminations, machining of the surface of the rotor will increase the hysteresis losses which, however, can be reduced by properly heating and cooling the complete rotor after all machining operations have been completed. This heating and cooling strain relieves the rotor teeth and tooth tips, or slot bridges, thus decreasing the hysteresis losses. It breaks the conductors away from the wall of the slots and tooth tips, or slot bridges, and adds some oxide for additional insulation.

The manufacturing of the die-cast rotor requires a close study of the proper methods and equipment that will produce a satisfactory product at the desired production rate and cost. The type of molds, gating, temperature, pressures, and purity of the metal are very important in obtaining solid homogeneous rotors that will be within the limits of the resistance desired.

Stray load losses can be checked only by rotating the rotor. The reverse rotation method of checking stray load losses has been successfully applied to production testing. This same method also will reject excessive rotor resistance. Closed slot rotors make it difficult to determine whether or not the slots are skewed. This method does a good job in picking out these rotors. A rate of 150 rotors per hour has been attained with this method of testing.

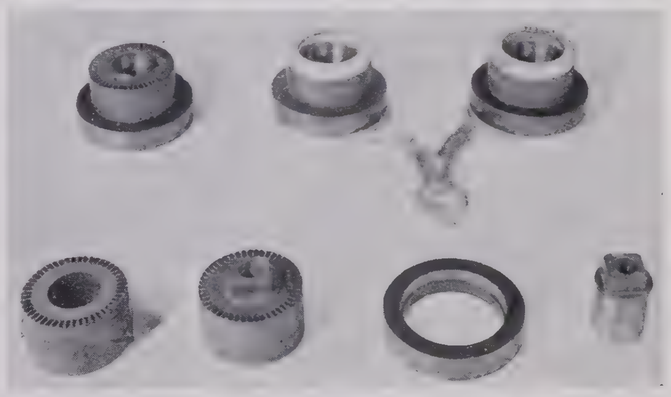

Figure 1. Sequence of operations in die-casting rotors

It is desirable sometimes to check rotors for porosity and its location when working out the gating and other problems of the die-casting process. There also may be some question about broken bars. Apparatus has been recently developed which will check both porosity and broken bars.

Experience has shown that proper study of the problem prior to production makes it possible to get production up to the desired rate quickly and economically and still maintain high quality and performance.

Digest of paper **49-69,** "Die-Cast Rotors for Induction Motors," recommended by the AIEE rotating machinery committee and approved by the AIEE technical program committee for presentation at the AIEE winter general meeting, New York, N. Y., January 31–February 4, 1949. Scheduled for publication in AIEE *Transactions,* volume 68, 1949.

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Heating of Radio-Frequency Cables

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IN CONSIDERING the heating of radio-frequency cables due to internal causes, there first must be determined the distribution and intensity of the generation of heat caused by the conductor and dielectric losses. Then the diffusion of the heat throughout the cable and its dissipation at the surface are considered in order to determine the resulting temperature rises at various locations in the cable.

Figure 1 shows a cable and the vector diagram of the voltage and current of the forward wave, E_a and I_a, traveling toward the load and of the reflected wave, E_b and I_b. Then, at any point

$$E^2 = E_a^2 + E_b^2 - 2E_aE_b \cos\psi$$

$$I^2 = I_a^2 + I_b^2 + 2I_aI_b \cos\psi$$

The rate of heat generation on either conductor is 0.24 I^2R calories per second, where R is the resistance per unit length of the conductor in question, inner or outer, at the frequency of the current. In the dielectric of power factor (pf), the rate of heat generation is 0.24 $(pf)\ \omega CE^2$, where $\omega = 2\pi f$ and C is the capacitance between conductors for unit length of cable.

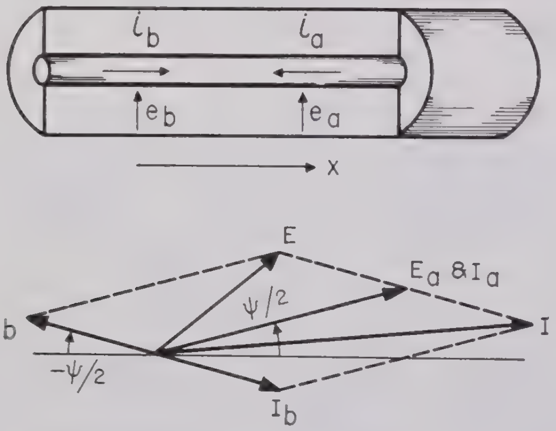

Figure 1. Voltages and currents on transmission line at time, t = 0

Each angle $\psi/2 = 2\pi x/\lambda$ where x is measured toward the generator from a voltage minimum

The heat may be separated into six parts: one constant along the length of the cable and another proportional to cos ψ for each of the two conductors and the dielectric. The equations of heat flow are linear, so the temperature rise due to each of these six causes can be determined separately, and the results added for the total rise. Furthermore, in the usual case, axial heat flow in the dielectric can be neglected with very little error.

In the steady state there is equilibrium between the heat generated on a section of the conductor of length, Δx, and the heat flowing out along the conductor and through the dielectric. The differential equation for this condition is readily set up, as is also that for the similar condition in an element of the dielectric.

When considering the flow of the heat generated on the conductors, the heat passing through the dielectric between cylindrical surfaces of radii r_1 and r_2 is $q = 2\pi k_p(u_1 - u_2)$ divided by $\log_e(r_2/r_1)$, per unit length.

The heat dissipated at the surface, per unit length, is $q = 2\pi r_s \mathcal{E}(u_2 - u_0)$ where r_s is the outside radius of the sheath, $(u_2 - u_0)$ the temperature of the outer conductor above ambient, and $\mathcal{E}$ is the effective heat loss coefficient of the outer conductor acting through the sheath.

For the part of the heat generation which is uniform along the length of the cable, the temperature rise above ambient of the inner conductor caused by heat generated on that conductor is

$$u_{11} = 0.24(I_a^2 + I_b^2)R_1[{}^1/_{2\pi r_s \mathcal{E}} + ({}^1/_{2\pi k_p})\log_e(r_2/r_1)]$$

For heat generated on the outer conductor, the rise of the inner conductor is

$$u_{12} = 0.24(I_a^2 + I_b^2)R_2/2\pi r_s \mathcal{E}$$

The rise due to dielectric heating is

$$u_{1p} = 0.24(pf)\omega C(E_a^2 + E_b^2)[{}^1/_{2\pi r_s \mathcal{E}} + ({}^1/_{4\pi k_p})\log_e(r_2/r_1)]$$

The variable parts of the heat generation such as 0.48 $I_aI_bR_1 \cos\psi$ produce temperature rises of a form $u = U\cos\psi$. Equations for U are somewhat long to be included in this digest.

As an example, the theoretical temperature rises in degrees centigrade of an *RG*-19/*U* cable delivering 5 kw to a load at 100 megacycles per second, with standing-wave ratios of 1.0 and 2.0, are found to be for the inner conductor:

Source of Heat	Theoretical Temperature Rise, Degrees Centigrade (Standing-Wave Ratio = 1.0)	(Standing-Wave Ratio = 2.0)
Inner conductor	23	29 + 13 cos ψ
Outer conductor	5	6 + 2 cos ψ
Dielectric	9	11 − 3 cos ψ
All sources combined	37	46 + 12 cos ψ

The magnitude of $U\cos\psi$ shown above is about one-half the value it would be if the thermal conductivity of the conductors were negligible.

Digest of paper **49-77** "Heating of Radio-Frequency Cables," recommended by the AIEE Electronics Committee and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 31–February 4, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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Professional Development of the Engineer in Industry

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Fourth to be published of a group of papers presented at a winter meeting symposium on education,[1–3] this article carries the young engineer into industry. Pointing out management's increasing appreciation of the value of continuing education, the authors discuss industry's responsibility toward the engineer's professional development, a responsibility that is embodied in two words—encouragement and recognition.

WE ALL have a stake in the professional development of the young engineer—industry, the colleges, and the technical societies. In the past, the engineer has played a leading role in scientific progress. Today, he also is taking an increasingly important part in industrial management. If the technological achievements of the past are to be used for the general welfare of the nation and for the protection of human freedom, the engineer must accept increasing responsibilities in public affairs. We must look to the young engineer for new leadership in industry and in the community. It is the job of industrial leaders and engineering educators to prepare him for these new responsibilities.

Industry has a special responsibility in the professional development of the young engineer. Not only do we as industrial people have an obligation to the engineering profession and to society, but we have a direct interest in building our own organizations. There is always a shortage of top-flight management and technical personnel. The solution to this problem lies in bringing present employees up through the organization by developing their capacity to fill responsible positions. As management encourages the supervisors throughout the company to take a greater interest in the training of the young engineers under them, the supervisors themselves grow in stature. Moreover, we owe it to the individual to provide him with the opportunity for further personal development. When a college graduate joins a company, he is making an investment of his time and talents in that organization. His future welfare as well as his usefulness to the company will be determined, in a large measure, by the type of training and guidance he receives. Accordingly, the new recruit has a right to expect his company to make an investment in his training and development. Such an investment will bring good returns to the company as well as to the individual.

THE HUMAN EQUATION

The broad professional development of the individual is an everyday job in industry. We in industry are working with the total personality of a man in a social situation. We take the individual where we find him and direct him toward worth-while pursuits. In the early stages, industry's approach is a basic one of orienting the new recruit to the company and the community, bringing him along in the right functional field, and encouraging him to continue his education. In this way, the young engineer builds a firm foundation for further growth. It must be a gradual process. As he experiences the maturing influences of his industrial work, he is better able to take the next step. There are, therefore, certain basic steps which the young engineer must take before he starts the second mile. You may call these steps preprofessional development, if you wish, but they are related significantly to ultimate success. The responsibilities and benefits of a professional status are only high-sounding phrases to the man who is a misfit on the job, who is insecure, or who feels he is being treated unjustly. A professional attitude, like happiness itself, is not something a person strives for, rather, it is a by-product of full participation in worth-while activities—productive labor, the family, and the community.

More thought should be given to training programs. As engineers and educators, we are interested in what makes things tick. But more than that, we are interested in what makes the ticker tick and why. The "why" is the important thing in engineering education. Since the questioning attitude has paid off so handsomely in the physical sciences, why, then, do we not adopt the same attitude in the solution of our professional development problems? To say that a program is good because it works is not a good enough answer, because it may not work tomorrow or ten years from now. We must know why a plan brings results so that we may continue to maintain an effective program in the face of changing conditions and continue to improve our methods. It is not to be implied that professional development is an engineering problem as such. Rather, we are suggesting the engineering method as an effective way of solving social problems. In the last analysis, the development of a professional man is a problem of education in human relations. Most of us will agree with Doctor E. Wight Bakke, director of the Yale University Labor and Management Center, when he recently said, "Human relations is our big unfinished job."[4] This applies to industry as it does to other segments of society. To know why a program works requires a better understanding of the young engineer's basic desires. Now we are getting down to fundamentals—the fundamentals of human relations.

Full text of a conference paper, "Professional Development of the Young Engineer in Industry," presented at a session on "Industry's Active Part in Education" held during the AIEE Winter General Meeting, New York, N. Y., January 31–February 4, 1949.

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They involve the aspirations of people and the factors making for enduring satisfaction; they explain why people react the way they do.

INDUSTRY'S JOB

It is gratifying, however, to know that real progress is being made. The engineering graduate is showing greater interest in continuing his development as a good citizen and improving his services to society. There is a growing appreciation on the part of industrial management that education is a continuing process. The large number of excellent training and advanced educational programs now in existence are evidence of the attention industry is giving this matter. But much remains to be done. Even at this late date, many employers make no provision to pick up the educational processes where the colleges leave off. In short, too many companies are not giving adequate attention to preparing their people for technical and management positions. According to a survey conducted by the Engineers' Joint Council, 50 per cent of the companies reporting did not have an initial training program for recent college graduates.[5] The results of a study made by the Engineers' Society of Milwaukee in the Milwaukee area revealed about the same percentage.[6] Apparently the management of those organizations is laboring under the misapprehension that the student is already a full-fledged engineer upon graduation and that managers are born. A good football coach would not think of trying to produce a winning team by turning 11 men on the field without any training and only the comment to go out and prove how good they are. Yet that, essentially, is what many firms are doing with their young recruits who, some day, will be expected to assume positions of responsibility.

In discussing what industry can do toward the development of a professional viewpoint, it must be recognized that the most impressionable years of the graduate's life are past by the time he reaches industry. This fact emphasizes the importance of the constructive influences which educational institutions can bring to bear on the young man. However, there is much that industry can do, especially for those who have a capacity for further growth. Precisely, what can industry do? Obviously a broad gauge program is required. The exact nature of the program and the methods of administering it will depend, of course, on the type of industry and the size, training experience, and background of the company. Small companies need a program as much as big organizations, but it must be tailor-made to fit their needs at a particular time. Accordingly, it is a mistake for a small company which never has done any formalized training to adopt the program and methods of a large company which has been training-conscious for many years. For it is true that methods change as a company builds up personnel experienced in training. It is better for a small company to set down a few practical objectives and then figure out what kind of a program will work and why. All that is needed to begin is the active support of top management and someone interested in seeing that the young recruit gets a good boost in his self-development. The important thing to remember is that training and development is a necessary function to be performed irrespective of the size of the company. While individual company requirements vary, there are, however, certain requisites for an effective development program which the authors feel are worthy of discussion. At the risk of oversimplification, the most important requisites are highlighted.

Create a Proper Environment. The first requisite for effective development is a favorable atmosphere in which to grow. This means an enlightened management which understands the human equation and fully recognizes that the greatest asset of a business is its human resources. It means a type of management which uses a man's abilities at the highest possible level and at the same time provides opportunities for further development. Unless such an atmosphere is prevalent, the best planned program will lack vitality. Of all the ingredients going into a successful business, trained personnel is the most important. That the young engineer needs encouragement and guidance is obvious. What may not be so apparent is that one of the best ways to develop professional attitudes is through association with men, who, themselves, have a healthful outlook concerning the job, our social institutions, and life in general.

Selection and Training. The second requisite is proper selection and effective training. The future of any business organization is dependent on the type of personnel it recruits and the quality of training provided. A company cannot long expect to maintain its position in the dynamic business world of today without making adequate provision for bringing in capable young men and developing them for key technical and management positions. If a business is to grow, it must have a flow of new blood into its various departments. The best source of new recruits will be found in the professional schools of the universities.

Careful screening of candidates is essential since a college diploma is not prima-facie evidence of fitness for a particular company. Progressive management realizes that errors in screening applicants not only deprive the company of good men, but result in the employment of misfits who prove costly in terms of turnover and employee dissatisfaction. In poor selection, a disservice has been done to the employee and the company. Management is looking for graduating seniors who are technically competent and who have the personal qualities necessary for success in industry. They want men who are trained thoroughly in fundamentals, who have a desire to get ahead, and who have the capacity to deal with people. Thorough training in fundamentals involves not only a clear understanding of the principles of science and the engineering method, but the capacity to apply them to the solution of everyday problems. In fact, the learning of fundamentals as ends in themselves stifles clear thinking and thus retards technical and professional growth. The colleges cannot, nor should they attempt to train for specialized jobs in industry. Rather, industry must assume its responsibility for providing orientation and job traning.[7]

In the Westinghouse company, the initial training program is known as the "graduate student training course," whose objectives are to give the recent college graduate an understanding of the company's organization and diversified activities open to him, to teach him methods of applying fundamental principles to the solution of industrial problems, and to assist him in finding the type of work for which he is best fitted by virtue of his educational background, aptitudes, and interests. In brief, it is a process of matching men and jobs and providing each man with the tools he needs to move forward. These objectives are accomplished through a series of co-ordinated work assignments, technical and professional conferences, and individual counseling in a well-defined program which extends over a period of approximately one year. This type of program gives assurance that the young engineer will receive personal attention from a sympathetic supervisor and will not become lost in the organization.

But initial training of the more or less formalized type is not enough. There is need for continuous development on an informal basis as the engineer moves along in his career. Job rotation broadens a man's experience and assists materially in developing future leaders. Flexibility in arranging jobs so that activities are fitted around the man rather than forcing him into a mold is advantageous at this stage of his career both from the standpoint of productivity and personal satisfaction. Intensive analysis of job requirements together with a more careful study of individual aptitudes and interests has resulted in better matching of men and jobs. Too frequently in the past, men without the necessary leadership qualifications were promoted to supervisory positions in order to give them added compensation for their accomplishments in technical work. Thus, industry lost the services of a good engineer and acquired a mediocre supervisor. A practical contribution to the solution of this problem was found in the establishment of job classifications with salary ranges of sufficiently high maxima adequately to compensate those particularly talented along technical lines. A promotion system based on individual performance together with insurance and pension plans contributes to the employee's peace of mind and thus creates a favorable condition for professional development.

Educational Opportunities. The transitional period from college to industry is a difficult one for the young engineer. Closing the gap between conditioning on the college campus and the realities of earning a living in a competitive situation is not an easy task. It is during these first few years that he is finding his place in industry, establishing his family, and shaping his professional concepts. Dean H. P. Hammond of the Pennsylvania State College in his fine article presented at the annual meeting of the Engineers' Council for Professional Development discusses the problems confronting the young engineer during his first few years in practice.[8] In this same article, he refers to the fact that this period frequently has been called the "post-college slump." In those instances in which the new employee is not given adequate orientation, the so-called "slump" often sets in immediately. Companies having a well-defined training program are not so likely to have that experience. There is, however, the ever-present danger of the "slump" occurring in the 3- to 5-year period following the completion of the formal training program unless management does something about it.

In addition to the follow-up training discussed in a previous section, a good preventive measure is that of encouraging self-development through courses at a nearby university. The best prevention, therefore, is a positive program of action. The engineer attains the status of a professional man only through experience and continued study. The importance of further study to enable him to recognize and handle the technical and the human factors in his engineering work cannot be overstressed. Experience has demonstrated that unless the engineer acquires habits of study and discriminating reading early in his industrial career, he rarely finds time later. Conversely, the man who starts early invariably keeps abreast of the changing scene. The stimulation resulting from classroom discussion under a capable teacher greatly accelerates the learning processes.

A substantial number of men engaged in research, development, design, consultation, and certain phases of manufacturing are not only qualified for graduate study, but actually need more advanced fundamental education. The sooner they get into a part-time graduate study program, the better. Herein lies a tremendously important area for closer industry–college co-operation which is not now being cultivated to the utmost. Others who find they are best fitted for sales engineering, manufacturing, and purchasing may benefit more directly by supplementing their engineering degrees with university courses in business, finance, and management. Both groups need a better understanding of the business economy and the social institutions under which they live.

Assuming that the engineer is reasonably well-grounded in scientific knowledge, and, therefore, is able to hold down an engineering job, the major problems which he will encounter will be problems of human and social relations. That a person can apply successfully the scientific method in the solution of a technological problem, and yet fail to use the same type of reasoning when faced with a social problem is, indeed, a paradox. The answer may be found in the theory that one does not carry over his orderly technical thought to another field if he does not understand the basic principles of that other field. It would seem then, that the young engineer needs to deepen and broaden his social knowledge and to exercise the art of using it in the solution of everyday problems.[9] Fortunately, engineering educators are fully aware of this need and are reappraising their curricula constantly in an effort to formulate a well-rounded program. The work in integrating the technical and social science courses and in formulating basic teaching methods now going on at the Carnegie Institute of Technology is one example. With a good start in college, the engineer can continue to increase his capacity to analyze business and social situations and reach reasoned decisions through experience, study, and a lively interest in human relations.

Encourage Professional Activities. The engineering societies and other professional groups have a significant part in assisting the engineer plan his self-development program. The eminently good work of the Engineers' Council for Professional Development, Engineers' Joint Council, and the engineering societies is well-known. Industry can do much to encourage technical employees to avail themselves of such programs and to take an active part in the local engineering societies. Participation in these activities engenders a sense of belonging and promotes a professional consciousness. An esprit de corps should be fostered in each society, but not to the extent that it blinds its members to an appreciation of the mutual advantages of working with all professional groups and other segments of society.

Through discussions with members of his own local branch, the engineer gains a deeper understanding of the ethics of his profession. The preparation and presentation of technical papers and reports not only builds self-confidence, but also generates further interest in expressing himself effectively and in learning more about techniques of communication. Such activities give him recognition both within his company and in his community.

GRADUATE STUDY IN INDUSTRY

One of the most fruitful areas for industry–college co-operation is through the inauguration of programs of graduate study for engineers who are engaged full-time in industry. Each year, industry employs a substantial number of graduates on the bachelor's level who are well-qualified for graduate work. After initial training, many are placed in activities which require a knowledge of advanced fundamentals. Industry, therefore, has an urgent need for late afternoon and evening classes on a graduate level. While only the employer can provide orientation to industry and job training, the teaching of advanced fundamentals can be handled best by the engineering colleges with the active assistance of industry.

True, there are many advantages to devoting full-time to graduate study. The company with which the authors are associated is interested in hiring a substantial percentage of master of science and doctor of philosophy degree men. Moreover, the company and the Westinghouse Educational Foundation sponsors a considerable number of fellowships at the colleges to encourage particularly talented young men to pursue graduate work on a full-time basis. Nevertheless, many top-flight students, for financial or other reasons, desire employment upon completion of their first degree. Furthermore, many of those who already have advanced degrees want to continue their education through formal classwork. The colleges and industry have a joint responsibility to strengthen and extend part-time graduate work so that the gainfully employed graduate can develop his abilities further and earn advancement in his company and the profession.

A number of educational institutions offer extensive programs of graduate courses for industry people. They are to be commended for their contributions. References should be made to the "Graduate Work in Industry" plan of the University of Pittsburgh, which is affiliated with several industrial concerns in the Pittsburgh area. The participating companies include the Aluminum Company of America, Philadelphia Company and subsidiary companies, Carnegie-Illinois Steel Corporation, Gulf Research and Development Company, Jones and Laughlin Steel Corporation, and Westinghouse Electric Corporation. The program was started jointly by the University of Pittsburgh and Westinghouse more than 20 years ago and has proved to be an outstanding success. To provide similar benefits to Westinghouse engineers in other cities, graduate study arrangements are maintained with New York University, Polytechnic Institute of Brooklyn, Stevens Institute of Technology, University of Pennsylvania, and Cornell University.

Westinghouse Graduate Study Program. Westinghouse Electric Corporation recognized the need for advanced fundamentals before the inauguration of the joint endeavor with the University of Pittsburgh. In 1912, B. G. Lamme, then chief engineer of the company, started a program of advanced fundamentals to train young men for design and development. This program, known as the advanced "design school," continues today. Realizing the high order of the work given, the University of Pittsburgh, in 1927, offered to grant graduate credit. This co-operative arrangement launched the graduate study program which was destined to become an extensive evening program, although the design school remains intact as a full-time day course.

In recent years, the evening plan has been enlarged a great deal. It now includes programs in engineering, mathematics, physical sciences, and business administration, although most of the employees are in engineering. The plan is open to all employees of the company who meet the requirements of the graduate school of the university. Courses are taught in the late afternoon and evening by both the resident faculty of the university and by Westinghouse scientists and engineers who have received appointment to the graduate school of the university. High academic standards are maintained by the university, and thesis work is under the direction of the Westinghouse graduate professor who is a resident member of the university's faculty. Normally, the thesis is based on the student's research or development work on the job. The classes are of interest mainly to the younger employees, but often experienced scientists and engineers, who already have their advanced degrees, enroll to keep abreast of the new developments in their own or other fields.

Such a program offers several advantages. The young engineer already knows something about the problems and methods of industry. As he becomes absorbed in his work, he soon feels a definite need for more advanced fundamentals. A realization of his shortcomings serves as a strong incentive to improve himself. Combining his classroom work and thesis research with his job vitalizes his graduate program, because the application of the principles to daily problems as they are learned makes those same principles more meaningful. In such an environment, engineering fundamentals and mathematics become tools for the solution of problems rather than mere excess baggage. Since, by necessity, the engineer specializes in his work, the program is of added value in that it assists him to maintain a broad scientific foundation for future growth.

The young engineer's desire for more scientific knowledge as a result of a recognized need, the fact that he can apply the fundamentals to the solution of everyday problems, and his realization that scientific knowledge is an engineering tool rather than an end in itself, contribute in no small measure to the success of the program.

The graduate study program is mutually advantageous to the University of Pittsburgh and the Westinghouse company. It serves as a 2-way channel which is so important in industry–college communication on mutual problems. The university secures the services of outstanding engineers who are not normally available for teaching and the company develops a group of leaders. Since the establishment of the program 22 years ago, some 4,700 employees have taken graduate courses for credit and many others have attended classes. The program has assisted in bringing good men into the company, in retaining them in the organization, and in preparing them for technical and management positions.

Although Westinghouse programs with the other five universities vary considerably in operating details, the objectives and results are the same.

Advanced Design Programs. Each year, two groups of carefully selected men are assigned to the electrical and mechanical design programs for a comprehensive investigation of advanced fundamentals in preparation for high-level work in research, development, and design. The objectives are the same as the original design school of B. G. Lamme. The men are selected for their general mental and analytical ability on the basis of competitive examinations, performance on engineering assignments, and personal interviewing. The students selected, working in small groups, devote full-time to study and reflection of fundamental problems under able leadership. The instructors are experienced engineers and scientists who have demonstrated their ability to do creative work and who have the capacity to inspire others. Such conditions are conducive to the development of ingenuity and the mastery of advanced fundamentals. Both the electrical and mechanical design programs carry graduate credit at the University of Pittsburgh.

ENCOURAGEMENT AND RECOGNITION

The master keys to professional development are embodied in two words: encouragement and recognition. The young engineer needs encouragment if he is to use his abilities at the highest possible level and is to develop his potentialities through experience and education. A breadth of scientific and social knowledge and the ability to apply it will increase his power to recognize and solve the technical, human, and economic aspects of his work, and will give greater assurance that he will assume his rightful place as a citizen. A young engineer needs to be given responsibilities, but no faster than he is able to handle them. To progress at the maximum rate commensurate with his ability, he must receive recognition for his accomplishments. A pat on the back for a job well-done and promotion for demonstrated ability acts as a powerful incentive to further self-advancement.

However, this is only part of the story, for in the final analysis all education is self-education. The development of leadership qualities and a professional viewpoint rests with the individual himself. But we should not be discouraged, for "All men desire by nature to know." This was true when Aristotle wrote it in Greek more than 2,000 years ago. It is true today. Aristotle's statement should be our charter for professional development. Our responsibility as industrial leaders and engineering educators is to point the way.

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Frequency Standards Broadcast

Time and frequency standards now are being broadcast by *WWVH,* radio station recently established by the National Bureau of Standards on the island of Maui, Territory of Hawaii. The purpose of the new station is to provide reliable standards at many locations not reached by station *WWV,* another Bureau station at Beltsville, Md. The effects of simultaneous reception in one locality of the two stations also will be determined.

WWVH operates on three carrier frequencies. They are 5, 10, and 15 megacycles. Accurate time signals in the form of audio-frequency pulses (0.005-second duration) are transmitted on each carrier frequency at intervals of precisely one second. On the 59th second of each minute, the pulse is omitted. Greenwich Mean Time also is given in International Morse Code every five minutes. The time announcements refer to the time when the audio tone returns. Call letters, *WWVH,* follow each time announcement.

Another service that is provided is the broadcast of a standard audio frequency of 440 cycles (A above middle C in the musical scale). The audio tone, starting exactly at the beginning of each hour, is transmitted for four minutes, and interrupted for one minute. This sequence is repeated throughout the hour.

The radio and audio frequencies and time intervals of one minute or longer are accurate to one part in 50,000,000 or better. Time signals are adjusted precisely with United States Naval Observatory time so that they will mark the hours and shorter intervals accurately. Seconds pulses from *WWVH* are synchronized to within 0.001 second with those sent out by station *WWV.*

Application of Diesel-Electric Locomotives

G. T. BEVAN

FORTY-FIVE PER CENT of the total operating expense of a railroad is affected directly by the character of the motive power used. Consequently, very careful consideration should be given to the proper selection of this power. From a strictly engineering viewpoint, a locomotive should be purchased as a tool to fit the job.

This approach of fitting the tool to the job in the selection of railroad diesel-electric power—as compared to the prior practice wherein steam locomotives were purchased and afterward tested with a dynamometer car to determine their hauling capacity—now generally is offered by locomotive builders. This practice not only fits the correct diesel-electric locomotive to the job, but also determines the economics involved, both from an initial investment standpoint as well as from an annual operating expense comparison.

With the advent of diesel-electric locomotives, a new approach to train operation had to be established. The diesel-electric can be overloaded to a point of damaging the electric equipment if tonnage and grade conditions reduce the locomotive speed below a given continuous speed. This is not true of steam operation, where a steam locomotive can be overloaded to the point of stalling without damage. Consequently, it was necessary for the manufacturer of diesel-electric locomotives to establish a continuous tonnage rating as well as a short-time tonnage rating for any particular locomotive application.

The use of speed-distance curves enables the engineering and economic aspects of a given application to be understood more readily. This graphic analysis is used as a basis for determining the fundamental application. It consists of the calculation of the operation of a train of predetermined size and weight at a certain speed over a given profile in such a way that a record of the complete running time as well as the continuous speed is obtained.

Furthermore, the correct size of diesel-electric locomotive for a given application can be selected from a preliminary investigation of the speed desired over the ruling grade with a given weight of train. Thence, by the use of the locomotive tractive-effort-speed curve from which the speed-distance chart calculations can be made and plotted by the step-by-step method, the speed and running time are determined over the entire run. In the usual manner, the grade, curve, and train resistance are added algebraically to the tractive-effort values from this curve to obtain the net tractive effort available for acceleration of the train.

The ability of a loaded train to make a rapid acceleration depends upon a number of conditions, the most important of which is the coefficient of adhesion between the locomotive wheels and rails. Numerous tests have proved that on a clean dry rail, a factor of 30 per cent is the maximum that can be attained without excessive slipping of the driving wheels. In the normal application of diesel-electric locomotives, rates of acceleration of 0.3 mile per hour per second for freight service and 0.75 mile per hour per second for passenger service have been determined as practical by experience. Variations from these rates depend upon the characteristics and type of train being accelerated.

With the use of speed-distance curves, an accurate determination of the fuel-oil consumption can be made readily from the calculated tractive-effort values. This is quite helpful in analyzing the fuel cost of diesel-electric as compared to steam power. The saving in fuel cost alone with diesel-electric operation may run as high as 60 per cent, depending, of course, on the relative cost of coal and diesel fuel oil. This saving in the fuel cost of locomotive operation is based on the fact that the diesel-electric has a thermal efficiency at the wheels of 25 per cent, whereas the corresponding figure for a modern steam locomotive is only five per cent.

Should the present price of diesel fuel advance to 20 cents per gallon, the cost of coal per ton for use in steam freight service would have to be $5.20 in order to match the fuel-oil cost. Any price higher than $5.20 would favor the diesel-fuel cost and result in a saving over steam operation. Further savings can be realized in the locomotive repair account. Steam-locomotive repair cost is, on the average, approximately ten per cent to 40 per cent higher than that of diesel-electric locomotives. Likewise, the engine-house expense account is another place where the use of diesel-electric locomotives shows considerable direct savings over steam operation.

In general, the direct savings can be further supplemented by reductions in the number of train miles operated and consequent labor changes. This is true because the diesel-electric locomotive can be operated in multiple-unit service in locations where double headings or extra sections are required with steam operation.

The net savings with diesel-electric operation on numerous railroads now operating this equipment indicate that the gross investment can be paid off in a relatively short time. From an initial investment standpoint, the relative first cost of steam motive power has advanced considerably in recent years, mainly due to the purchase of custom-built designs as well as to there being less equipment manufactured as compared to the diesel-electric locomotive. Consequently, on a dollar-per-horsepower basis, the operating savings with diesel-electric motive power appear very attractive.

Digest of paper **49-42,** "Application Engineering on Diesel-Electric Locomotives in Railroad Service," recommended by the AIEE land transportation committee and approved by the AIEE technical program committee for presentation at the AIEE winter general meeting, New York, N. Y., January 31–February 4, 1949. Scheduled for publication in AIEE *TRANSACTIONS*, volume 68, 1949.

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Modern Trends in Room Lighting

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FELLOW AIEE

An ideal luminous environment for persons doing close visual work, such as in offices and classrooms, requires adequate light with an absence of excess contrast in the visual field. Recent experiments conducted at the Massachusetts Institute of Technology indicate the superiority in this respect of the new luminous ceiling, over the louverall ceiling which is being employed in many recent installations.

ROOM LIGHTING today is experiencing rapid changes. New lamps, new luminaires, and new methods of lighting are being tried. Some of these innovations are based on sound physiological and psychological research and are likely to endure, but others violate fundamental principles and are mere passing fancies. To assess the modern trends in lighting, with particular reference to schools, the administration at Massachusetts Institute of Technology appointed a lighting committee in 1946. Some of the conclusions of the committee are presented in this article for the use of others faced with the problems of ideal illumination.

REQUIREMENTS

To provide a luminous environment for people who are doing close visual work, we need two things: enough light, and a 3-to-1 helios (brightness) ratio.

The first requirement is obvious and needs no comment. The second deals with the fact that excessive contrast in the visual field must be absent if eyestrain is to be eliminated. It now is realized generally that both glare and troublesome shadows are banished and a pleasing psychological effect is produced of the helios (brightness) of the brightest surface in the room does not exceed three times the helios of the work, and if the helios of the work does not exceed three times that of the darkest surface in the room. This criterion has been recommended by the Illuminating Engineering Society[1] and provides the lighting engineer with the simplest single rule for obtaining excellent quality in lighting.

As indicated in Table I, a 3-to-1 helios (brightness) ratio cannot be obtained when bare lamps are employed, even though these lamps are of the fluorescent type and are louvered. It is found that a 3-to-1 ratio requires an apparent source of very large area, which is obtained most effectively by using the entire ceiling as source. Evidently we may use either a reflecting ceiling or a transmitting ceiling, which gives us two possible methods of high-quality lighting. In the former, the ceiling is painted white and light is thrown onto it from below. In the latter, a hung

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The authors acknowledge the interest and help of James R. Killian, president of the massachusetts Institute of Technology, also the co-operation of numerous others who made possible the experimental installations discussed in this article.

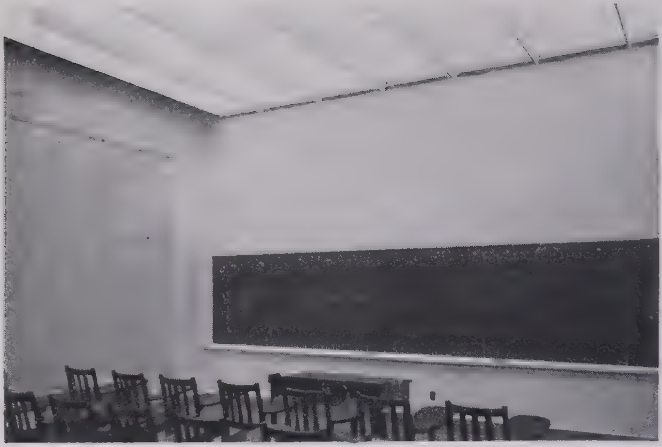


Figure 1. Classroom with a luminous ceiling of diffusing plastic

A 2-to-1 helios (brightness) ratio is obtained between ceiling and white paper on the desk, so there is nothing in the room that is excessively bright and both direct and reflected glare are absent. The room falls short of the ideal because of the dark chalkboards and furniture, which were not changed when the room was relighted

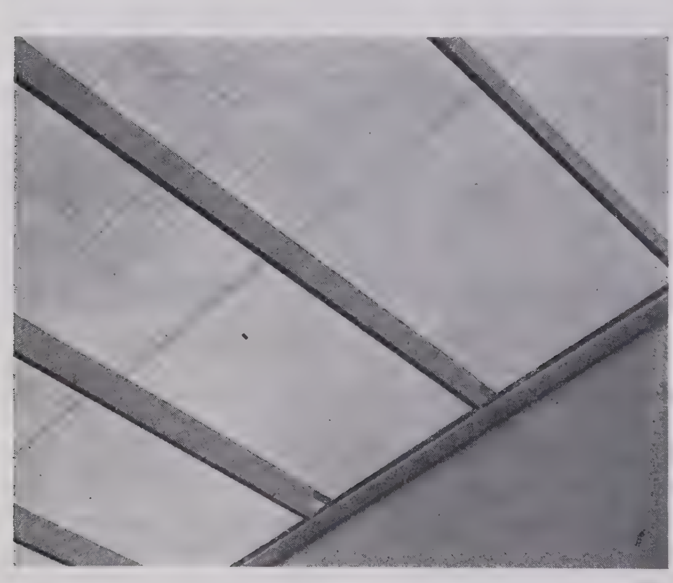


Figure 2. View of the luminous ceiling, showing the perforated steel supporting beams and the corrugated plastic diffusing sheets

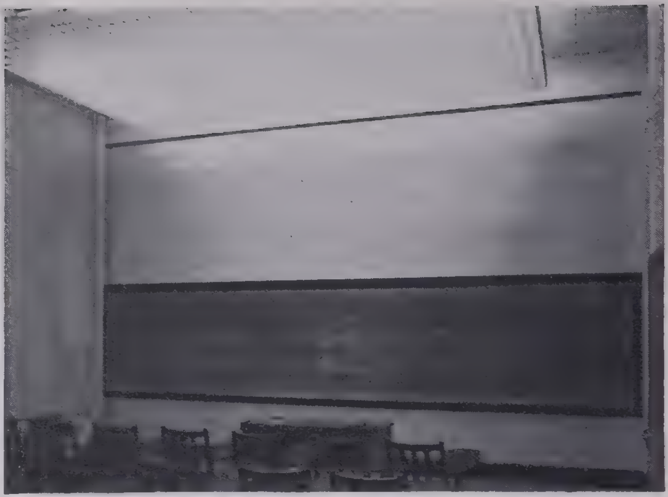


Figure 4. Classroom showing a louverall ceiling used with 40-watt T-17 fluorescent lamps

ceiling of translucent material is interposed between the lamps and the room.

Perhaps the simplest way of obtaining a luminous ceiling by reflection is to use hanging luminaires that direct most of their light toward the ceiling. The parts of the luminaire that are visible from below should be made of a dense translucent material whose helios (brightness) is not widely different from the ceiling helios. Several luminaires of this type are now commercially available. An experimental luminaire, designed by the lighting committee, is shown in the headpiece. Each luminaire consists of two half cylinders, an upper one of transparent plastic and a lower one of diffusing plastic. No metal bars or other opaque parts are

Table I. Approximate Average Helios (Brightness) of Some Fluorescent and Incandescent Lamps

Lamp	Helios (Blondel)	Helios Ratio*
40-watt, *T-17*, 4,500 degrees white fluorescent	9,900	24.7
40-watt, *T-12*, 4,500 degrees white fluorescent	17,300	43.3
96-inch *T-8* at 200 ma	17,700	44.2
at 300 ma	23,200	58.0
32-watt circular fluorescent	22,000	55.0
60-watt *A-19* incandescent, inside frost	70,000	175
100-watt *A-21* incandescent, inside frost	120,000	300
200-watt *PS-30* incandescent, inside frost	130,000	325
500-watt *PS-40* incandescent, inside frost	200,000	500

* The second column gives the approximate helios (brightness) of the lamp, expressed in the modern mks unit—the *blondel*. A perfectly diffusing surface has a helios of one blondel if it emits one lumen per square meter. Helios in blondels is converted to brightness in foot-lamberts by dividing the number of blondels by 10.76.

Some incandescent lamps are included for comparison because they might be employed with a louverall ceiling, or they might (in the smaller sizes) be exposed to view. The third column of Table I gives the approximate ratio of lamp helios (brightness) to helios of white paper at table level. An incident pharosage (illumination) of 500 lumen m^{-2} (46.5 lumen $feet^{-2}$) is taken, and the paper is assumed to have a reflectance of 0.80.

The helios (brightness) ratios depend, of course, on the pharosage (illumination). For instance, if 250 lumen m^{-2} is used instead of 500 lumen m^{-2}, all tabulated ratios must be doubled. In any case, however, the ratios are much greater than the desirable value of 3 to 1.

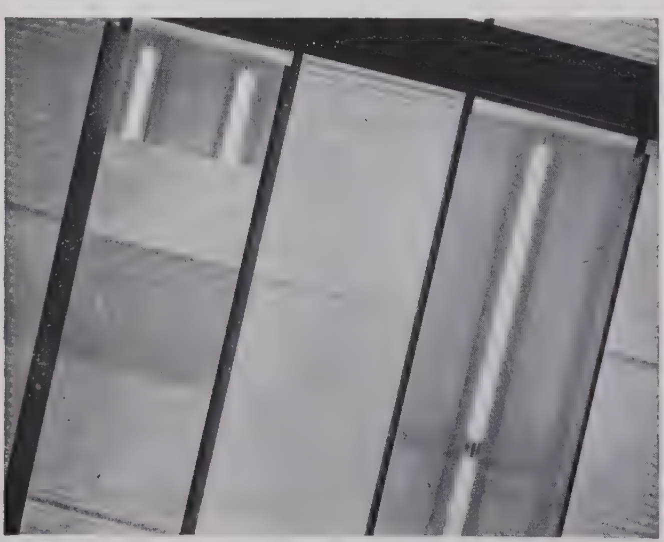


Figure 3 (left). The plastic panels are easily slid aside for relamping and cleaning

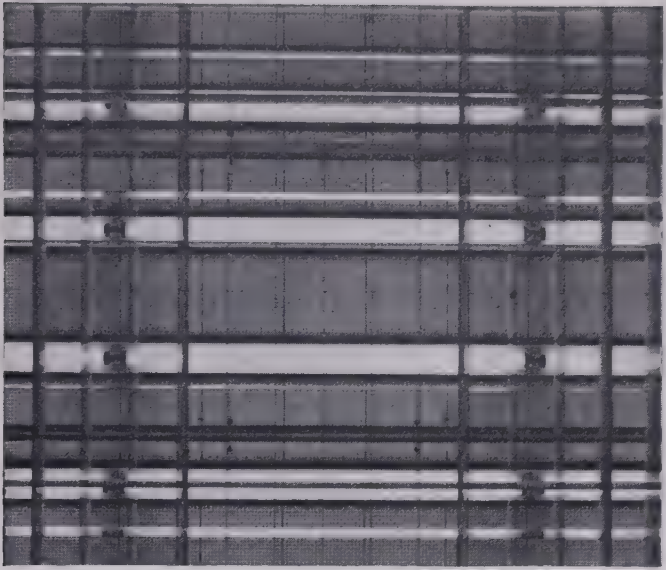


Figure 5. Looking up at the ceiling of Figure 4

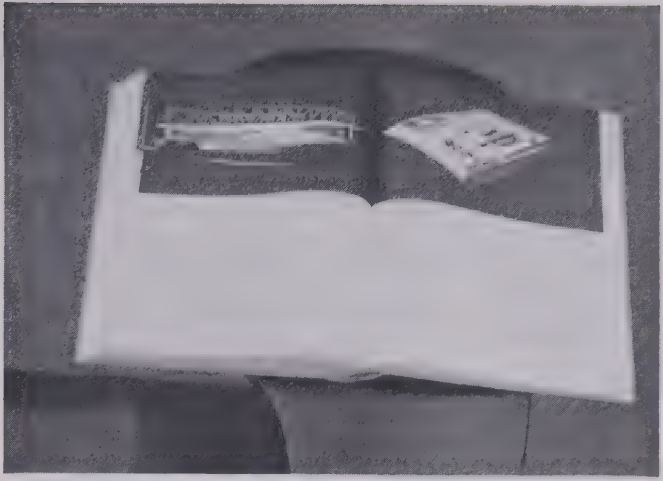
used on the sides. Each luminaire contains two 96-inch *T-8* fluorescent lamps and the maintained luminous output is high because of the dust-tight construction. When used with highly reflecting room surfaces (ceiling at least 80 per cent, walls at least 50 per cent, floor and furniture at least 30 per cent), such luminaires satisfy the 3-to-1 criterion and provide an ideal luminous environment.

The other way of obtaining excellent visual conditions is to use a hung ceiling of diffusing plastic. Figure 1 shows a typical classroom lighted in this way. The 72-inch *T-8* fluorescent lamps are mounted directly on the structural ceiling. Forty-four of these lamps are employed and are spaced 24 inches apart and operated at 200 milliamperes. The total load is 2,200 watts or 3.26 watts per square foot. The average pharosage (illumination) at table level is approximately 60 lumens per square foot (foot-candles).

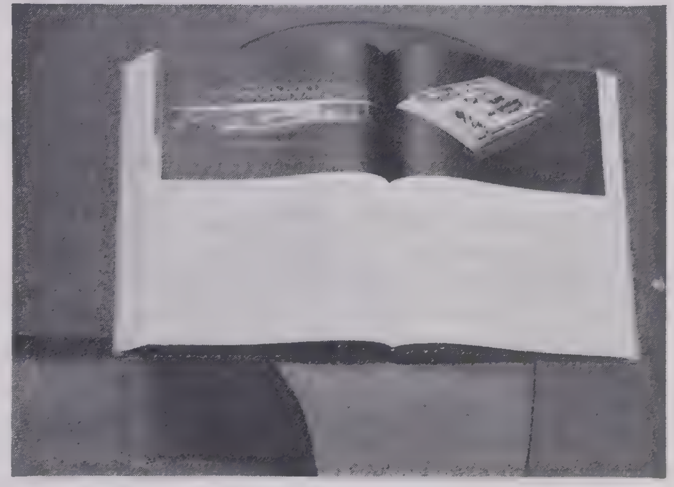
Approximately 18 inches below the true ceiling are perforated steel beams six inches deep, containing acoustic absorbing pads which provide the acoustic treatment for the room.* Resting on these beams are sheets of one-eighth-inch diffusing plastic approximately 36 by 48 inches (Figure 2). The sheets are corrugated for greater stiffness. They are moved easily to allow access to the lamps, as shown in Figure 3. Without treatment, the reverberation time of the classroom was approximately four seconds; but this value was reduced to approximately one second in the finished room.

COSTS

As would be expected for a pioneer installation, the cost of lighting the room (Figure 1) was rather high.** Table II shows that the total cost of lamps, ballasts, and wiring (done by a local contractor) was $1,125, or $1.67 per square foot. The supporting structure and acoustical material, installed, cost $0.89 per square foot, while the plastic cost $1.43 per square foot.



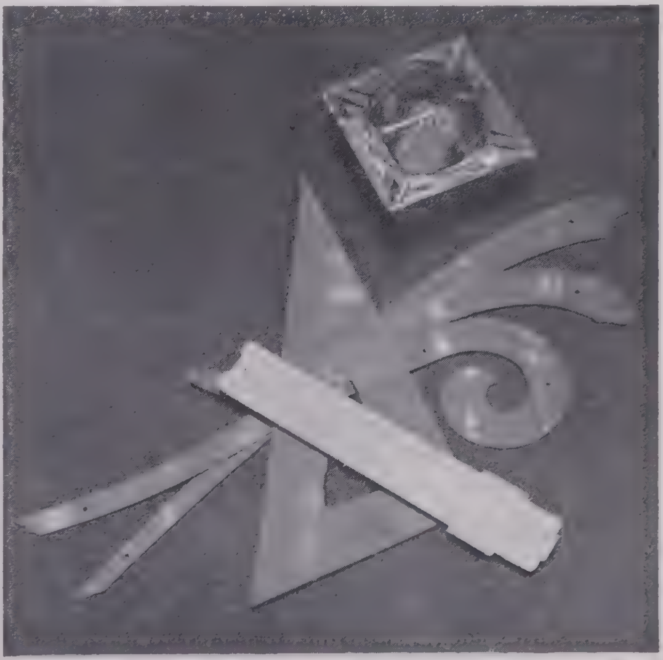
A—In room of Figure 1



B—In room of Figure 4; note specular reflections of lamps in book and furniture

Figure 6. Appearance of a book under a luminous ceiling and a louverall ceiling

Figure 7 (below). Annoying reflections of louvered lamps (in room of Figure 4)



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* The authors are indebted to the Massachusetts Institute of Technology acoustics laboratory for collaboration on the acoustic design.

** Though not as high as if a louverall ceiling had been used to provide the same amount of light.

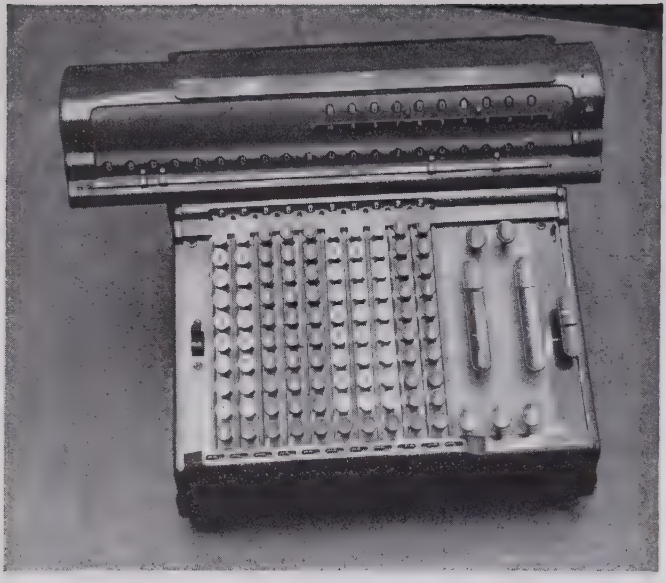

Figure 8. Louvered lamps reflected in a computing machine

How can these costs be reduced in future installations? With larger rooms, or several rooms relighted at the same time, the labor cost per lamp would be lowered somewhat. Also, if the user is satisfied with less light, the number of lamps can be reduced proportionately. The most promising item of economy, however, is the diffusing plastic. Thinner sheets can be obtained for 60 cents per square foot. Or plastic-impregnated paper, costing about one cent per square foot, can be stretched on metal frames and can be renewed easily if it becomes damaged. It would seem that careful design might allow the transmitting luminous ceiling to be produced at a cost no greater than that of other high-quality lighting systems.

THE LOUVERED CEILING

Because of the recent use of the louvered ceiling in a number of lighting installations, a direct comparison between it and the uniform luminous ceiling seemed advisable. Accordingly, a louverall ceiling was installed in an exactly similar classroom adjacent to that of Figure 1. The appearance is shown in Figure 4. Lighting was provided by 36 40-watt *T-17* "low-brightness" fluorescent lamps mounted on the ceiling. White enameled steel louvers with 45-degree cutoff were hung below the lamps. The total load was 1,950 watts (2.88 watt feet^{-2}) and the average pharosage (illumination) at desk level was approximately the same as for the luminous ceiling.

The principal weakness of the louverall ceiling is suggested by Figure 5. Though the louvers usually eliminate direct glare, they have no effect on reflected glare which may be a very potent source of eyestrain. Figures 6 to 8 show examples of reflected glare, experienced in the louverall room but absent with the luminous ceiling.

Table II. Cost of Installing an Experimental Luminous Ceiling

	Cost	Cost Per Square Foot
Lamps, ballasts, and wiring	$1,125	$1.67
Acoustic beams, fabricated and installed	597	0.89
Diffusing plastic	968	1.43
Total	$2,690	$3.99

The great defect of most lighting installations has been excessive helios (brightness) variation. The luminaires have been too bright, the floors and furniture have been too dark. The modern trend is toward the use of lighter colors throughout the room, combined with large light-sources of low helios (brightness). In this way, a 3-to-1 helios (brightness) ratio can be obtained, resulting in an ideal luminous environment and excellent conditions for seeing. These conditions can be attained by use of luminous indirect luminaires (headpiece), or complete luminous ceiling (Figure 1). Several groups of people have used the luminous-ceiling room for long periods of exacting visual work and were enthusiastic about it. The louverall ceiling on the other hand, is inherently wrong since it does not eliminate reflected glare (as proved by Figures 6 to 8).

REFERENCE

1. Report of the Committee on Standards of Quality and Quantity of Interior Illumination, Illuminating Engineering Society. *Illuminating Engineering* (New York, N. Y.), volume 41, 1946, page 361.

Heat Propagated as "Sound"

The well-established heat-propagation trio of conduction, convection, and radiation, now has a fourth member. Scientists at the National Bureau of Standards, working with temperatures near absolute zero, have obtained a heat flow which has a wave motion analogous to sound. Appropriately enough, they have dubbed the phenomenon "second sound."

"Second sound" occurs within the substance, helium II. At 2.19 degrees Kelvin, ordinary liquid helium undergoes a transition to helium II with a radical alteration of many of its properties. Some scientists believe that this material constitutes a fourth state of matter. They attribute "second sound" and other remarkable behavior to the presence in helium II of a superfluid. The atoms of this superfluid have had their energies reduced to the point where thermal motion almost has ceased. Yet the intermolecular forces are not great enough to produce a rigid solid.

Unlike ordinary sound, of course, "second sound" is generated thermally, and can be detected only by temperature-sensitive devices. At the bureau, the soundlike heat waves were studied using a pulse method. Several quatities, including velocity and attenuation, were measured.

In the pulse method, an oscilloscope triggers a multivibrator at the same instant that it begins its horizontal time sweep. Electrical pulses from the multivibrator generate heat pulses within the helium, which travel through the fluid as "second sound," and are detected by a temperature-sensitive element. The resultant faint voltage signals are amplified by an audio amplifier and impressed upon the vertical plates of the oscilloscope to give an easily detected visual signal.

Temperature Rise Values for D-C Machines

AN AIEE COMMITTEE REPORT

FIVE manufacturers have tested motors rated at 0.5, 5, 10, 25, and 50 horsepower for temperature rise on an exchange motor test program at the request of the AIEE committee on rotating machinery. The purpose was to determine the relation between the internal hot-spot temperature rise and the temperature rise measured by the resistance method, thermometer method, and surface thermocouple method. These relations were determined for both continuous-load heat runs and for short-time heat runs. The motors tested were all general-purpose, open 40 degree centigrade, 1,750-rpm motors.

Table I. Limiting Observable Temperature Rises

	Method of Measurement	Temperature Rise											
		General Purpose	Totally Enclosed		Short-Time Rated						Special Purpose Continuous*		
		Continuous			30-Minute to 2-Hour Ratings, Inclusive			Ratings of 15 Minutes or Less					
Class of insulation		A	A	B	A	B	H	A	B	H	A	B	H
Armature windings	Thermometer	40	55	75	55	75	100	55	75	100	50	70	90
	Resistance	50	65	85	80	110	140	90	120	160	60	85	110
Shunt field windings	Thermometer	40			55	75	100	55	75	100	50	70	90
	Resistance	60	70	90	70	90	120	70	100	130	70	90	120
Single-layer field windings with exposed copper	Thermometer	50	65	85	65	85	110	65	85	110	60	80	100
	Resistance	50	65	85	80	110	140	90	120	160	60	85	110
Cores and mechanical parts	Thermometer	40			55	75	100	55	75	100	50	70	90
Commutators and collector rings	Thermometer	55	65	85	65	85	110	65	85	110	65	85	112
		1	2	3	4	5	6	7	8	9	10	11	10

* Generators having a 2-hour, 25 per cent overload rating will have temperature limits ten degrees lower than given in columns 10, 11, and 12 for the continuous load; and the same as given in columns 4, 5, and 6 at the end of the 2-hour overload.

Based on the results, a table of limiting values for temperature rise similar to Table I of ASA-C50 is constructed. The new table is worked out from the test data starting with limiting values for the thermometer method as given in Table I, ASA-C50,[1] without change. Many years of successful experience has established these limits for the thermometer method as satisfactory. Therefore, no change is made in thermometer values for class-*A* or class-*B* insulated machines. For class-*H* insulated machines, limiting values for the thermometer method have been originated as this class is not covered in Table I, ASA-C50. To originate these values, the maximum hot-spot temperature of 180 degrees centigrade has been taken, and allowance has been made for the difference between hot-spot temperatures and surface temperatures. This allowance, which is subtracted from the hot-spot temperature rise, is taken as the same percentage of the hot-spot temperature rise as AIEE Standard Number 1[2] presently allows. Resulting values are rounded off to nearest multiples of five.

Limiting values for the resistance method are established by multiplying each thermometer value by the respective ratio, determined from the tests, of rise measured by resistance to rise measured by thermometer. This ratio is applied for each class of insulation. The results of the tests using surface thermocouples were found to be equivalent, for all practical purposes, to the results using thermometers.

In the case of stationary, shunt, field coils, and for short-time rated machines, the hot-spot temperatures corresponding to the time-honored thermometer limits are found to be higher than heretofore recognized. For example, the hot-spot temperature rise consistent with the rise allowed by ASA-C50 for thermometers for the motors tested (class *A*) was found to be 65 degrees centigrade instead of 55 degrees centigrade now recognized for shunt field coils. Rather than reduce the time-honored allowance of 40 degrees centigrade rise by thermometer, it appears reasonable in the case of stationary field coils not to change the thermometer standard and to recognize the corresponding hot-spot temperature rise as 65 degrees centigrade.

In order to be consistent with the standard 55 degrees centigrade as the temperature rise allowed by thermometer for short-time rated machines, the test data indicate 80 degrees centigrade as the corresponding hot-spot class-*A* temperature rise.

For class-*A* machines rated 15 minutes or less, the hot-spot rise corresponding to 55 degrees centigrade rise by thermometer is 100 degrees centigrade except for shunt field coils where the hot-spot rise is only 80 degrees centigrade. The reason for the lower ratio of hot-spot rise to thermometer rise in the case of the shunt field coils is that the surface temperature of the shunt coils on very brief load runs generally is raised rapidly by radiation from the commutating field winding.

The new table, Table I of this article, is more realistic and more comprehensive than the present Table I of ASA-C50. Following more tests and conclusive discussion of results, revision of Table I, ASA-C50, is recommended.

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1. American Standard Rotating Electric Machinery, ASA-C50. American Standards Association, New York, N. Y., 1943.

2. General Principles Upon Which Temperature Limits Are Based in the Rating of Electric Machines and Apparatus. AIEE Standard Number 1, June 1947.

Digest of paper **49-62,** "Temperature Rise Values for D-C Machines," recommended by the AIEE rotating machinery committee and approved by the AIEE technical program committee for presentation at the AIEE winter general meeting, New York, N. Y., January 31–February 4, 1949. Scheduled for publication in AIEE *Transactions,* volume 68, 1949.

Personnel of AIEE Subcommittee on D-C Machines: T. M. Linville (*chairman*); Mrs. B. O. Buckland; W. E. Clancy; F. A. Compton, Jr.; Lanier Greer; J. L. Hamilton; C. B. Hathaway; V. P. Hessler; W. R. Hough; P. Lebenbaum; C. Lynn; L. G. Opel; D. Ramadanoff; J. F. Sellers; V. B. Honsinger; L. N. Grier.

Measuring Air Velocity With a Thermopile

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A NEW-TYPE anemometer has been developed which allows velocities as low as five feet per minute to be determined as accurately as the higher velocities. It operates by placing a heated thermopile in an air stream whose velocity is to be measured. The flow of air past the thermopile tends to bring the thermopile wire, consisting of a succession of thermojunctions, to the same temperature throughout. The thermal differences between these junctions induce a thermal direct voltage which is proportional to the temperature differences. Thus, flow of air past the thermopile tends to reduce this temperature difference and therefore, to reduce the direct voltage generated by the thermopile.

Normally, maximum voltage is obtained with zero air velocity, and zero output represents a large cooling effect by a high air velocity. However, when high accuracy is desired over a wide range of velocities, a second series of thermocouples can be arranged with opposite polarity and shielded from any air currents. With these couples arranged to buck the voltage from the velocity pickup thermopile, zero voltage output is obtained for zero air velocity and full-scale indication of the indicating or recording instrument is obtained for the particular air velocity desired. Sensitive instruments of this type are well-suited to process control, the rapid response of the electric signal operating controls and giving warning of deviations.

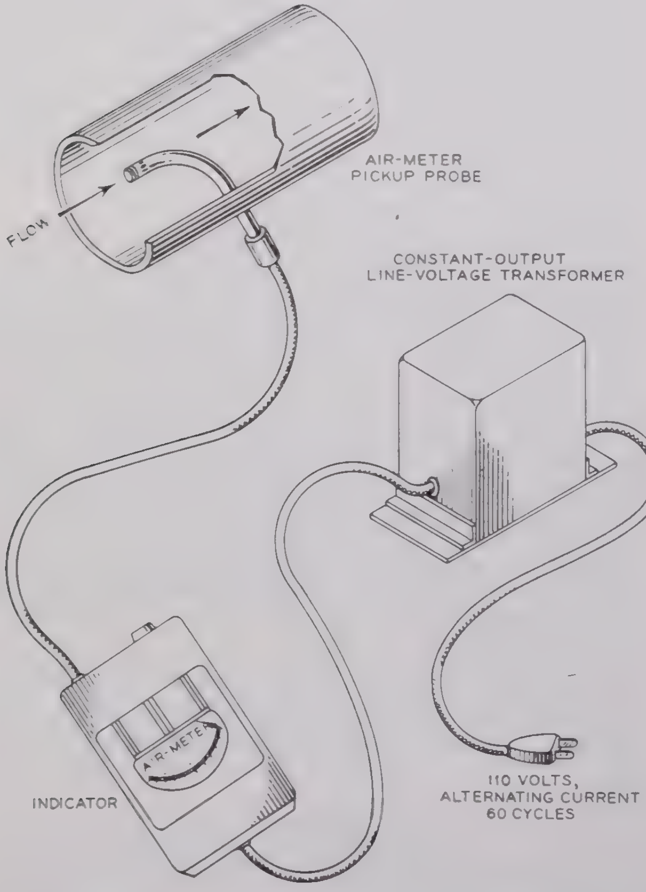

Figure 1. Air meter being used as a flowmeter

This type of anemometer, with no moving parts and with an ability to measure velocitites as low as five feet per minute, is especially well suited for use in air-conditioning, ventilating, and heating work. A 2-thermocouple arrangement which lends itself readily to an inexpensive type of construction has been incorporated into a standard low-cost model designed primarily for this type of use. The indicating air meter, seen in Figure 1, is small and can be held easily in the palm of the hand while taking readings. The thermopile element is in a separate probe which may be plugged directly into the indicating meter, or which may be used at the end of graduated extension wands or flexible cables. By incorporating this thermopile element in a pipe or duct, the direct-voltage output can be calibrated to indicate or record a rate of flow of air or gas through the pipe. Figure 1 illustrates this type of use. When used as a flowmeter, this type of instrument has several distinct advantages over the usual types of thermal instruments which record the temperature rise across a heater as a measure of flow. The power requirements are much less, since the entire mass of gas flowing does not have to be raised in temperature. Also, the unit causes a minimum of pressure drop across the measuring element.

Experience has proved this type of thermal anemometer to be exceptionally stable. One instrument has operated continuously for a year in the laboratory and a second instrument, designed for indication of nondirectional air flow, has operated for the same period on top of a building and has consistently indicated wind velocity without failure or zero shifts. Errors introduced due to change in air temperature are compensated for since both cold and hot junctions are equally affected by any change in ambient temperature. Likewise, radiation effects tend to cancel. Thermal anemometers have no moving parts to introduce frictional errors which are very important in low-velocity measurements. Also, they are not affected by icing.

The unit is well adapted to remote recording on standard strip-chart potentiometers or other standard types of indicating or recording instruments which operate from direct voltage. The ability of anemometers of this type to measure extremely low velocities, combined with their inherent stability, ease of operation, low power requirements, and adaptability to remote indication or recording, suggests many applications of a widely varying nature.

Digest of paper **49-23**, "A New-Type Instrument for Measuring Air Velocity," recommended by the AIEE instruments and measurements committee and approved by the AIEE technical program committee for presentation at the AIEE winter general meeting, New York, N. Y., January 31–February 4, 1949. Not scheduled for publication in AIEE *Transactions*.

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A Time Division Multiplexing System

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This system features pulse amplitude modulation with a filtering arrangement for minimizing the required transmission band width. A discussion of the channelizing, synchronizing, transmission equipment, and system performance data is included in the article.

ELECTRICAL engineers working in the communications field are concerned with transmission systems for carrying messages over long distances with maximum fidelity. Usually such systems have terminal equipment for multiplexing many narrow band channels into a single wider band channel before transmission is started. Terminal equipments usually are divided into two groups according to their method of multiplexing. The frequency division group has been used widely,[1,2] and there have been many recent developments in the time division groups.[3,4] However, the time division systems previously described have required a transmission band width many times greater than the band width of the original total intelligence. Because of this, time division terminal equipments heretofore have been applicable only to radio relay systems employing pulse modulation. The terminal equipment described in this article utilizes time division multiplexing but is characterized by requiring a transmission band width approximating that of the original total intelligence. This low transmission band width requirement makes the terminal equipment adaptable for use with either amplitude- or frequency-modulated transmission systems. The techniques to be described are applicable to amplitude-modulated pulse multiplexing systems. The system described uses linear amplitude modulation but pulse code modulation systems may be considered as a particular example to which these same techniques also may be applied.

As the art of radio relaying at microwave frequencies has advanced, the engineering problems inherent in the art have been defined more clearly. The direction of one solution to these problems is the use of a low band width time division terminal equipment in association with a relay system using a frequency-modulated carrier. If the required transmission band width is sufficiently low the relay system may use either subcarrier modulation[5] or direct modulation with heterodyne remodulation.[6] With these transmission problems in mind the specific requirements for a multiplex terminal equipment which would function most effectively with a radio relay or coaxial cable transmission system were given attention. Out of this work has come the multiplexing system to be described.

GENERAL DESCRIPTION

The equipment is a time division system. The usual sending terminal has multiple band inputs, timing generator, sampling gates, and the combining stages from which the sending terminal output is derived. Amplitude-modulated signals are handled throughout this equipment. Figure 1 is a block diagram of the sending terminal.

A carrier oscillator with a 60-kc sinusoidal output is used to trigger an 8-kc pulse generator. This is accomplished by frequency doubling and counting circuits together with gate circuits to insure uniform timing intervals. The pulse generator is arranged to have a generally triangular pulse output. The delay line distributor is a lumped constant transmission line or low pass filter made up of M derived sections such that its total time delay is 125 microseconds equally divided into 30 intervals of 4.16 microseconds. This line has a characteristic impedance of 2,500 ohms and a bandwidth of approximately 300 kc. The pulse generator output is applied to the line and the combination provides a traveling delay line signal which may be used to successively gate 30 band modulators at an 8-kc rate. The band modulators may have a voice-band signal, or other signal with a frequency range of 60 to 3,300 cycles, applied to their inputs. The output of any individual modulator will be a pulse signal similar in shape to the delay line pulse signal but modulated in amplitude in accordance with the input signal amplitude at the time of application of the delay line signal. The time spaced outputs of all of the modulators are combined into a pulse train as shown at output terminal, A. In order properly to index the receiver, one band modulator is modified to have two input terminals. One input is normally a 3,900-cycle indexing tone supplied from a suitable oscillator and the other input may be a voice-band or order-band input having a frequency range of 60 to 2,500 cycles.

In conventional pulse amplitude modulation systems, output at A would be recognized as the normal sending terminal output signal. It could be applied to any transmission medium having suitable passband characteristics. In the case of a microwave radio relay system the signal could be used to frequency-modulate the carrier or subcarrier of the radio relay. The output signal of the transmission medium should be a replica of the input signal ready for application to the receiving terminal equipment.

The receiving terminal equipment also follows the general pattern of similar time division systems. If the signal from output terminal, A, is applied to the receiving terminal input it is necessary that we first produce and maintain proper registration or indexing of the voice bands, and

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Essentially full text of paper **49-25**, "A Time Division Multiplexing System," recommended by the AIEE communication committee and approved by the AIEE technical program committee for presentation at the AIEE winter general meeting, New York, N. Y., January 31–February 4, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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second, demodulate the voice bands. Indexing and synchronizing are accomplished as two separate steps. The indexing problem is solved by the modulation of one of the bands by a tone slightly above the normal voice-band passband such that the particular band is characterized by an unusual constant tone modulation. The receiving terminal then is equipped with a single band having a means for recognizing this tone and indexing thereon. Until indexing is accomplished, the synchronizing circuits are disabled and the receiving terminal timing generator repetition rate is made slightly different than the sending terminal timing generator repetition rate so that slippage occurs between the received band pulses and the receiving terminal gating pulses. When the proper channels are in register, the slip circuits are disabled and the receiver terminal timing generator then is driven by the synchronizing circuits operating on the received signal. Synchronizing is accomplished by the transmission of band repetition rate frequency components in the sending terminal signal. The signal energy of this frequency, called the carrier, is separated from the composite signal and, after amplification, may be used to control the timing generator in the receiving terminal. In order to index the receiving terminal, a slip frequency oscillator is used as shown in Figure 2. The oscillator is crystal-controlled to a frequency approximately 30 cycles higher or lower than the 240-kc carrier frequency of the sending terminal. During the indexing period, this slip frequency signal is applied to counter circuits and the timing generator to produce a delay line pulse as in the sending terminal, except that the repetition rate of this pulse is slightly slower or faster than the sending terminal pulse rate. Accordingly, there is a gradual drift of the receiver input signal with respect to the delay line keying signal. During each cycle of the slip frequency, one-thirtieth of a second in this case, the bands drift into proper registration. During this brief interval of proper registration, the input signal is applied to the band separators as will be described. The presence of the indexing signal in its assigned band indicates proper register of the band pulses and the receiving terminal separators, and this signal energy may be used therefore to operate a changeover circuit. This circuit, during the indexing interval, has connected the slip frequency oscillator to the timing generator.

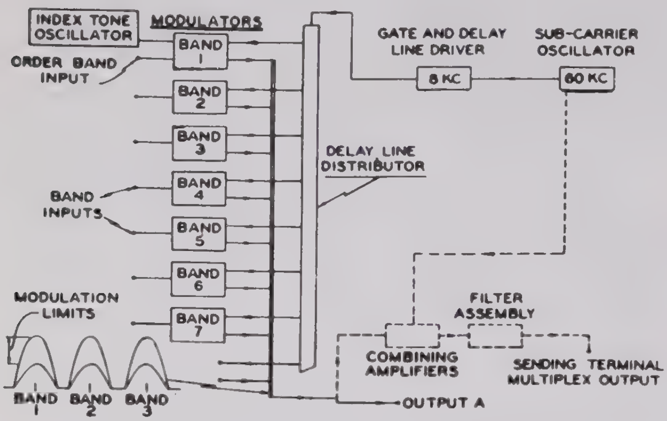


Figure 1. Sending terminal block diagram

Once the bands have been indexed, the circuit discards the slip frequency oscillator and connects the derived sending terminal carrier signal to the timing generator, thus locking the receiving terminal gating rate to the sending terminal sampling rate.

Proper indexing is insured by the deliberate modulation of one voice band with a tone which is higher in frequency (3,900 cycles) than the signals permitted in any other voice band, and by the provision in the corresponding voice band at the receiving terminal of a sharp band-pass filter responsive to this tone.

This indexing circuit has been given rigorous tests and has been found to index in less than one-thirtieth of a second after signal interruption and to hold the receiving terminal in proper register with received signal to noise ratios as low as zero decibel.

Voice-band demodulation is obtained by the progressive gating of pulse separators with subsequent filtering and amplification of the modulation energy of the band pulse spectrum. The gating is derived from the delay line distributor as explained.

The foregoing general description of the terminal equipment indicates one system whereby the basic functions of band multiplexing, indexing, and synchronizing may be performed. If an adequate transmission system were interposed between the sending and receiving terminals the desired band output signals could be obtained.

THE SENDING TERMINAL OUTPUT SIGNAL

When one has terminal equipment of the type just described, the problem of a transmission medium becomes most important. In our considerations we have been restricted primarily to the use of microwave radio relay systems and our study has concentrated on the known faults of such systems. Since all types of radio relays cannot be considered in this brief article, we shall consider the relay system which appears to be superior. Such a relay uses frequency modulation of the carrier and either a heterodyne-

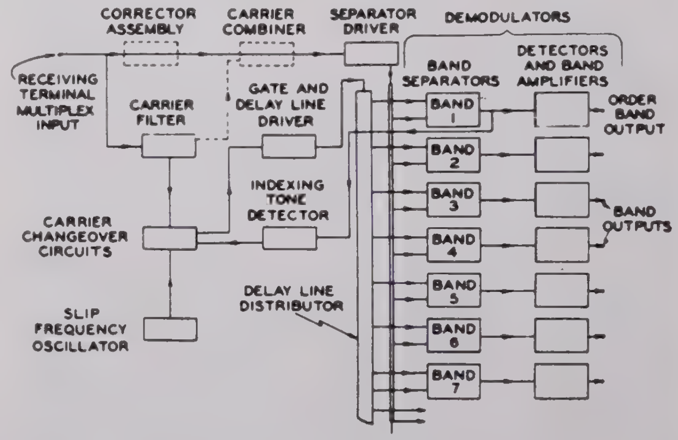


Figure 2. Receiving terminal block diagram

type repeater or a locked oscillator type of repeater. With a wide-band relay of this type it is possible easily to maintain good signal to noise ratios at reasonable modulation band widths; but on account of the wide carrier frequency deviations used, the amplitude linearity of the system is not exceptional unless elaborate precautions are taken. These two primary factors, along with minor features, indicated that a time division multiplex system would match such a relay system best. With time division, only the signal of one channel is ordinarily present at any instant, hence the amplitude linearity and signal to noise ratio of the relay system need only be that required by the requirements of any single voice band. Harmonic distortion does not cause beat notes or noise in other bands. Further, distortions of the relay output signal due to multipath or other propagation or transmission defects will not be observed except as for their direct effect on each voice band individually.

Thus observing the advantages of time division multiplexing from the point of view of the radio relay requirements, we were disturbed by its one largest disadvantage; namely, that a modulated pulse train such as indicated at output terminal, *A*, of Figure 1 obviously required a band width far in excess of the band width of the intelligence being transmitted. In fact, for 30 voice bands representing approximately 100 kc of intelligence (neglecting guardbands), a low pass band width of approximately one megacycle would be required to satisfactorily resolve the sending terminal output pulse train. Work on this phase of the project has progressed successfully and a technique has been developed whereby the required transmission band width is comparable to the total input intelligence band width by virtue of a coding arrangement using amplitude division. That is, the signal amplitude is shared among a few channels in a fixed proportion determined by the sending terminal equipment.

The apparatus for minimizing the required band width is shown as the filter assembly on the output of Figure 1 and the corrector assembly at the input of Figure 2.

The filter assembly of Figure 1 performs the function of limiting the high-frequency end of the spectrum of the signal from the sending terminal; thus the transmission equipment is called upon to handle a narrower band of frequencies than would be required otherwise. That this filtering function can be performed without distorting the modulation information in each voice band is evident from the Fourier analysis of the pulse train. Assuming a pulse train subject only to pure amplitude modulation (with no distortion of the pulse shape), this analysis shows the spectrum of the pulse train to be a fundamental frequency, corresponding to the basic sampling rate (8 kc) and its harmonics, each having an upper and a lower sideband produced by modulation. Thus modulation of one band will produce, in addition to the band repetition frequency energy and its harmonics, a spectrum of energy including the original modulation spectrum plus the band sampling rate and its harmonics, each of the latter having an upper and lower sideband. To discard some of the high-frequency energy of this composite spectrum without distortion of the modulation information, it is required that the distribution of energy among the sampling frequency and its harmonics be a constant when the pulse train is modulated. This can be accomplished only with a modulator which is free of all modulations (width, shape, and so on) other than amplitude.

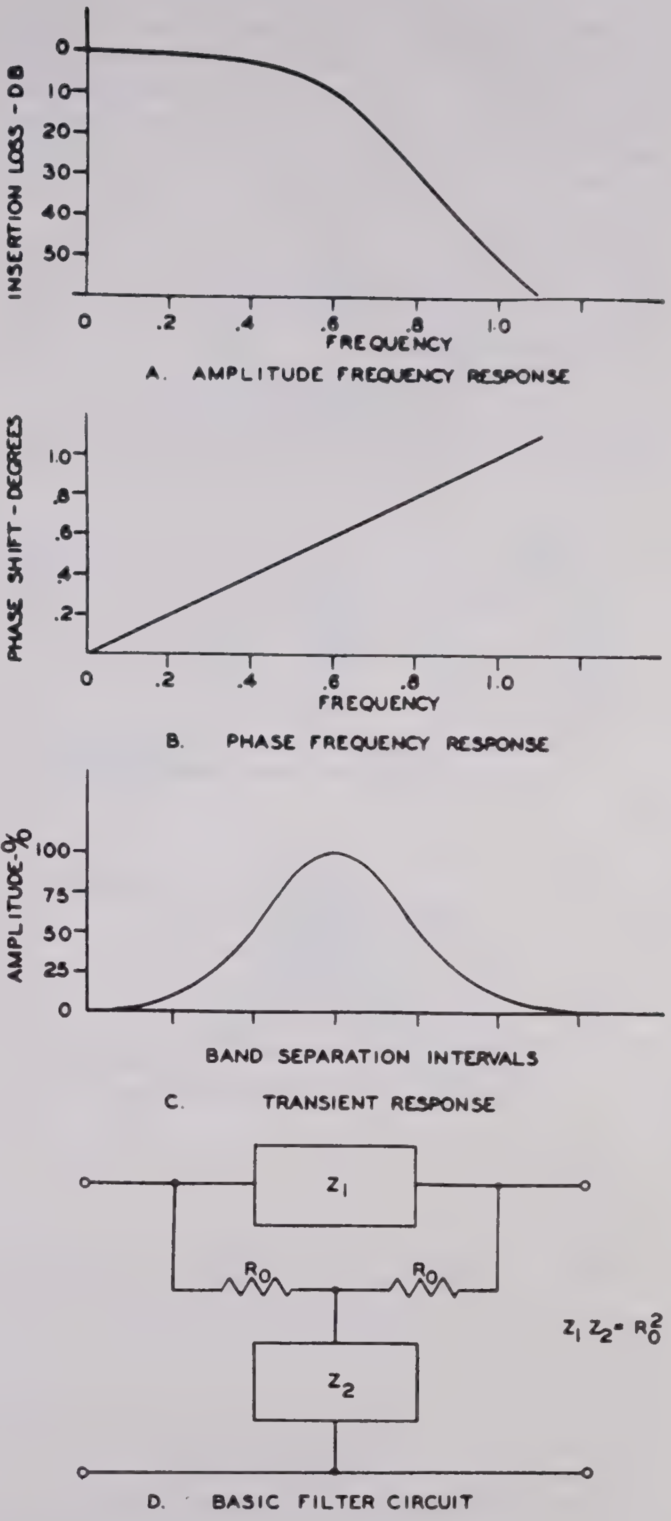


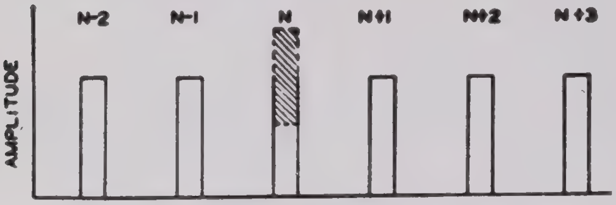
Figure 3. Ideal filter characteristics

If the foregoing requirements are met, the result of proper low pass filtering may be summed up as a failure to define the original pulse train. Therefore, a single band pulse is widened so as to overlap one or more adjacent band pulse intervals. The degree of this effect depends on how severely the band width is curtailed and upon the transient response of the filter. This broadening of the pulse width by filtering, and its consequent overlap in time with the signal pulse of another band, results in a sharing of the total signal voltage from the sending terminal among a number of channels, and in the need for a compensating unit at the receiving terminal.

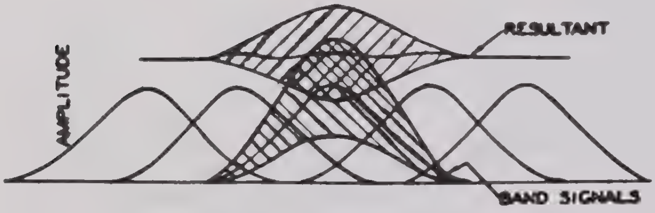
The extent of the basic pulse broadening is calculable from a statement of the transient response of the filter. A filter with a symmetrical transient response approximating an error function shape

$$f_t=e^{-a^2t^2}$$

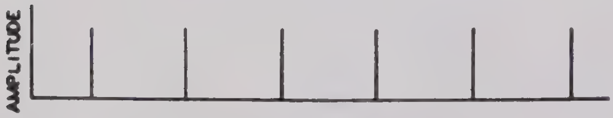
has been used for most applications. The typical responses of one such filter are shown in Figures 3*A* and 3*B* along with a calculated output pulse spread showing, in Figure 3*C*, corresponding interference in adjacent channels. In other applications a filter having a nonsymmetrical transient response possesses some advantage. Once a set of characteristics has been settled upon, the construction of the filter may be undertaken. It must be understood that since we are dealing with pulses, we are most interested in the transient response of the filter and not in its amplitude or phase response alone.



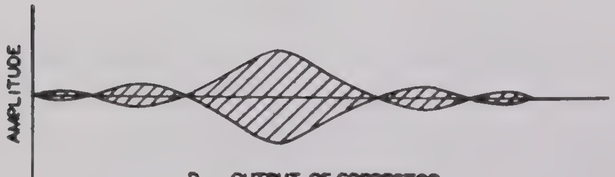
A. IDEALIZED BAND PULSES BEFORE FILTERING



B. RESULTANT OF FILTERING BAND SIGNALS



C. DETECTOR GATING INTERVALS



D. OUTPUT OF CORRECTOR

Figure 4. Diagram of corrector operation

One actual filter unit used to accomplish this reduction in band width is a low pass network of the constant resistance bridged-*T* variety,[7] successive sections of the composite network not necessarily being identical. A statement of the general characteristics which such a network ought to possess may clarify the design problem. Having specified a cutoff frequency at which the output shall be more than 40 decibels below the input, the variation of the transmission characteristics of the network for frequencies up to this limit are of concern. Certain responses are more desirable than others inasmuch as they make the compensation problem at the receiving terminal less complicated. A filter network whose characteristic transient is symmetrical and whose damping factor is just sufficient to prevent overshoots will provide, in general, a minimum of interference with adjacent bands.[8] The transmission characteristics of a network having such a characteristic are that the amplitude-frequency response is a gradual slope throughout the pass band, while the phase frequency response is zero at zero frequency and increases linearly until after amplitude cutoff is reached. These responses are indicated in Figure 3*A* and 3*B* and serve to define network performance. The filter network chosen approaches these ideals quite closely with reasonably few parts and critical adjustments. The general form of one section of the network is shown schematically in Figure 3*D*. In cases where a nonsymmetrical transient response is desired it has been found most expedient to obtain such responses by adding to the filter a required pattern of phase equalizing circuits which are used to obtain the desired response without modifying the filter amplitude response.

In summary, the sending terminal output is a pulse train which has been so filtered as to narrow the frequency spectrum of the signal energy while permitting a division of the instantaneous amplitude of the output signal among adjacent channels. Of course, from the filter characteristics, the amount of signal energy caused by each channel is known, and at the receiver use is made of this known information.

During field testing of this system of multiplexing using radio relays as the transmission medium, it was verified that, if desired, a relay system with a poor transient response might be used with this pulse system by accounting for the change in pulse shape introduced by the relay when making the initial receiving terminal setup adjustments. This is of great importance in any practical radio relay network.

In preceding paragraphs it was noted that synchronization of the receiving terminal was obtained by the recovery of the carrier frequency. When a filter of the foregoing type is used it will be recognized that the normal carrier frequency, which is the 240-kc signal, is fully attenuated. The requirement for a carrier frequency signal at the receiving terminal is met therefore by the addition to the filtered output pulse train of a subcarrier which is at a frequency within the filter transmission band. There are two groups of choices for this subcarrier frequency: It may be a harmonic of the band sampling rate, or it may be midway between such harmonics. In the first case, the receiving terminal input signal will show different voltage levels for successive signal bands but will not produce any undesired modulation signals. In the latter case, each voice band will be modulated at a 4-kc rate due to the nonintegral relation of subcarrier and sampling rate but such 4-kc signals may be rejected by the modulation recovery device. Either system is usable and a subcarrier at 60 kc is shown in Figure 1. The amplitude of the added subcarrier is controllable and a level of less than 10 per cent of the peak signal has been found in practice to be more than adequate.

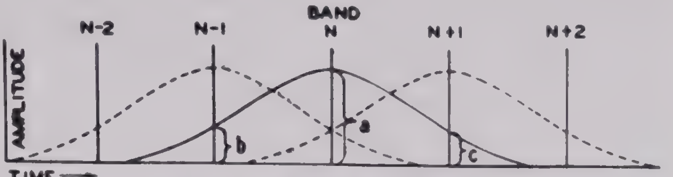
It now remains to add in the subcarrier frequency to the output of the filter and the signal output of the sending terminal is complete. Derived from the crystal-controlled oscillator as shown in Figure 1, the subcarrier frequency is run through a band pass filter of conventional design to eliminate undesired harmonics, phased to an advantageous position with respect to the composite output, and added thereto.

THE RECEIVING TERMINAL CORRECTOR CIRCUITS

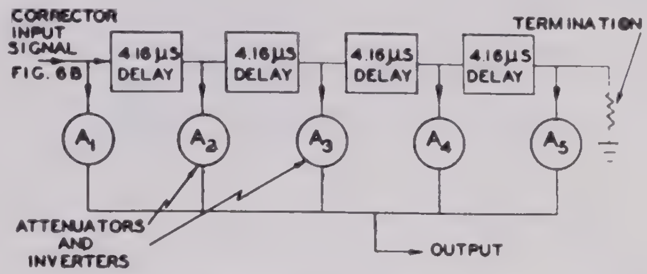
It is one of the design aims of the receiving terminal common band equipment to remove the mutual interference between channels, which interference was controllably introduced in the sending terminal, as completely as possible. At the same time, the equipment to accomplish this should remain simple, easy to adjust, and stable with time. The operation of the compensation system employed is based upon knowledge of the relative amplitude of the output of the sending terminal at time intervals corresponding to adjacent bands on either side of the interfering band in terms of the output of the interfering band. In other words, for any band combination in which mutual interference results, it always is known that the interference of one band on another is a fixed per cent of the peak of the interfering signal amplitude, the percentages of interference being specified by the filter transient response.

Figure 4 shows in some detail the results of filtering a typical multiband amplitude-modulation pulse train by a symmetrical transient filter. Figure 4*A* is an idealized section of the pulse train from the sending terminal multiplex before filtering, with six of the band pulses present in the portion shown. If a band circuit is modulated the modulation may vary the pulse amplitude between the limits shown crosshatched, and the crosstalk in adjacent bands will be known from the filter characteristics. As an example, the filter characteristics have been chosen to give adjacent channel crosstalk only. Figure 4*B*, therefore, shows the component contributions of each band and the resultant output at the filter output terminals. In order to make clear the fact that the receiving terminal channel detectors respond only to the peak of the modulation spread produced by the filtering action, it is emphasized that gated peak detectors are used, timed by the carrier transmitted with the multiplex signal. Interference of band N with bands $N-1$ and $N+1$ is readily visible as Figure 4*C* shows the effective gating function which the receiving terminal detectors exhibit. At the times labeled $N-1$ and $N+1$, corresponding to the opening of the band circuit separators, it is apparent that some signal from band N will be present also. It is the purpose of this discussion to show how this interference may be eliminated. However, the interference will be corrected to zero only at the time of the indicated gating instants.

Basically, the corrector operates to cause the signal of a band to be zero at all times spaced by the band interval from the peak of the band modulation; that is, interference will be zero at the gating intervals of all other bands. Figure 4*D* illustrates a typical corrector output for the input signal of Figure 4*B*. It will be observed that the resultant signal amplitude is zero at the gating time of all bands other than the originally modulated band. Thus band interference has been eliminated. The block diagram for a corrector network which might be used to eliminate the interference shown by Figure 4*B* is shown in Figure 5*B*. It may consist of a series of delay networks driven from one end with each delay unit having a time delay equal to the band interval. From the junctions of these networks, signals are fed through unilateral attenuators and polarity inverters, as required. They then are added to produce an output voltage which, therefore, is used to energize the band separators.[9]



A. REPLICA OF BAND SIGNAL VOLTAGE IN CORRECTOR NETWORK AT TIME INTERVALS EQUAL TO BAND INTERVAL



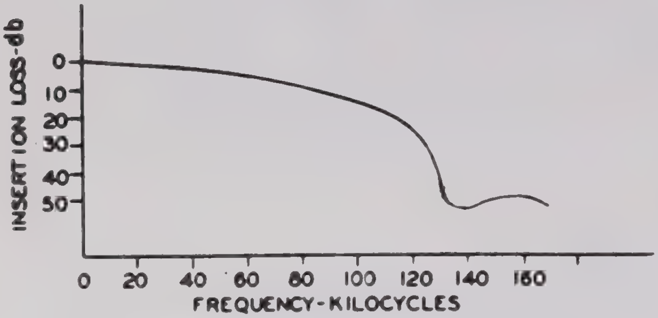
B. BLOCK DIAGRAM OF CORRECTOR

C. Table of Output Voltage

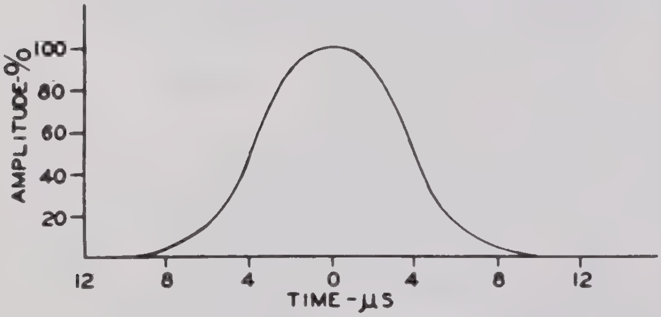
Time	Output
N	$bA_2+aA_3+cA_4$ = desired signal
$N-1$	$bA_1+aA_2+cA_3=0$
$N+1$	$bA_3+aA_4+cA_5=0$
$N-2$	$aA_1+cA_2=0$
$N+2$	$bA_4+aA_5=0$
$N-3$	cA_1 = residual interference
$N+3$	bA_5 = residual interference
$N-4$	0
$N+4$	0

Figure 5. Corrector characteristics

A proper adjustment of the attenuators permits the use of the signal of any band to cancel its own interference with all other bands. The operation may be visualized as follows: as the signal of any band passes through the delay network the total output of the network is equal to the amplitude of the signal at that time, as shown in Figure 5*A*, multiplied by the corresponding attenuator gain. These outputs are tabled in Figure 5*C* for successive band gating intervals. By equating the outputs to zero at the adjacent band intervals the settings for the attenuators are calculable.



A. AMPLITUDE FREQUENCY RESPONSE



B. TRANSIENT RESPONSE

Figure 6. Typical filter characteristics

In other cases, attenuator settings can be likewise readily found experimentally when the equipment is initially adjusted.

For complete correction of interference to absolute zero at all times an infinite number of delay networks and attenuators would be required. However, the cancellation process can be made to converge rapidly for many useful transient responses such that, in practice, for as much as 30 per cent interference in adjacent channels only six networks are required to reduce the crosstalk in all bands to negligible values. As an illustration, the table of Figure 5*C*, indicates a residual output at channel $(N+3)$ and $(N-3)$ gating times. This ordinarily will prove to be a negligible value, but it may be reduced as far as desired by the addition of more corrector networks.

The final practical limit to which this band width reduction system can be extended has not yet been determined. However, to date the 30-channel 240-kc pulse train system described has been operated successfully through a filter system having the amplitude characteristic of Figure 6*A* and a transient response of Figure 6*B* with a 10-section corrector reducing all crosstalk to 45 decibels below the output signal level.

CONCLUSIONS

A study of the transmission characteristics of the sending terminal filter assembly and the receiving terminal corrector assembly when connected in series and a consideration of their effect as a transmission medium on the signal to noise ratio of the signal has proved to be interesting. The calculations and equipment tests verify the conclusion that the band width of a transmission system for use with the filter described by Figure 6*A* need not exceed 120 kc. Since the corrector adjustments have been found in practice to be stable and easy to adjust, the use of the techniques described makes possible the transmission of time division multiplexed signals over a low band width cable or over a radio relay system employing frequency modulation of the carrier. The high modulation indexes now possible with frequency modulation transmission systems result in favorable output signal to noise ratios.

From these characteristics it will be clear that no signal energy at frequencies above approximately 120 kc are required for the transmission of the complete signal. This compares favorably with the requirements for single sideband amplitude modulation transmission, yet retains the features of pulse transmission. Of course, since the system is a pulse system, attention must be paid to the phase response throughout the entire pass band. It also will be understood that a low pass filter ordinarily is used ahead of the receiving terminal input to eliminate any high-frequency noise which may have been added to the signal by the transmission system. This filter need be only slightly wider than the filter at the sending terminal, in order for its effect on the system transient response to be negligible. The amount of transmission loss inserted at frequencies above 120 kc makes no difference in the system operation.

During the field tests, the Western Union Telegraph Company made available its radio relay circuits and its multiplexed telegraph voice-band load signals for the comprehensive testing program. From these tests the principles of operation were confirmed and new designs accommodating a greater number of voice bands are now in progress.

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Voltage Dip in A-C Generators

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THE MAGNITUDE and duration of the voltage dip during sudden application of load to an a-c generator under regulator action often is required to determine disturbance to other equipment on the system. Point-by-point methods, although accurate, require considerable time to apply. An analytical solution has been used covering machines with self-excited exciters operating below appreciable saturation. The first few cycles generally were disregarded as this permits neglecting the effect of dampers and subtransient voltage drop.

To take the subtransient voltage drop into account, the application of load is considered as a short circuit through external impedance. The terminal voltage with fixed excitation is then expressed as

$$e_t=(e_2''-e_2')\epsilon^{-\frac{t}{T_{d_1}''}}+(e_2'-e_2)\epsilon^{-\frac{t}{T_{d_1}'}}+e_2 \tag{1}$$

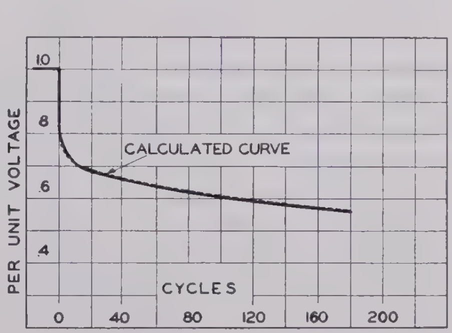
where

T_{d_1}'' = subtransient short-circuit time constant, corrected for load; T_{d_1}' = transient short-circuit time constant, corrected for load; e_2'' = generator terminal voltage immediately after load change, assuming internal reactance is X_d''; e_2' = same based on X_d'; e_2 = same based on X_d.

Expressions for e_2'', e_2', and e_2 depend upon the nature of the load, but are simple to compute if the load current is essentially linear with voltage as for starting a large motor. Figure 1 shows the general shape of this decay curve as calculated and tested on a 40,000-kva unit.

To account for appreciable saturation in the exciter, or for use on large machines with pilot exciters, the main exciter voltage build-up curve is expressed as

Figure 1. Stator voltage with fixed excitation; full load added



$$e_x=e_{x1}+(e_c-e_{x1})\left(1-\epsilon^{-\frac{t}{T_e}}\right) \tag{2}$$

where

e_c = exciter ceiling voltage with generator field connected; e_{x1} = initial exciter voltage; T_e = exciter build-up time constant.

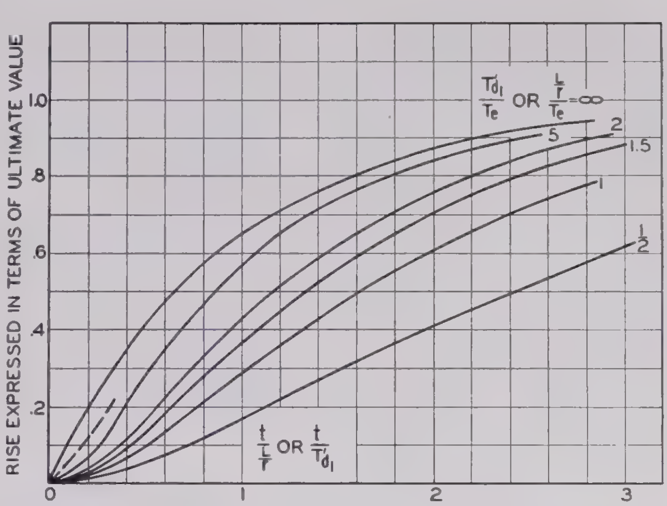


Figure 2. Build-up of field current or terminal voltage

When this voltage is applied to the collector rings of the alternator, the field current may be shown to be

$$i_f=i_{f1}+\frac{(e_c-e_{x1})}{r\left(r-\frac{L}{T_e}\right)}\left[\left(r-\frac{L}{T_e}\right)-r\epsilon^{-\frac{t}{T_e}}+\frac{L}{T_e}\epsilon^{-\frac{r}{L}t}\right] \tag{3}$$

where

i_{f1} = initial field current; r = field resistance in ohms; L = field inductance in henrys (assumed constant).

To facilitate application of equation 3, the initial field current, i_{f1}, is disregarded and the second term of the right-hand member is plotted in Figure 2 as a fraction of its final value against time, expressed in terms of the field time constant L/r. For each L/rT_e, only one curve applies.

Because of eddy currents in the solid metal parts, the flux does not increase as quickly as the field current. The time constant governing the flux is found to agree closely with the corrected short-circuit time constant, T_{d_1}' when the curves of Figure 2 are employed using T_{d_1}' instead of L/r. The ordinates from Figure 2 are multiplied by $(e_c-e_{x1})/e_{x1}$, and by the sustained voltage component, e_2. The products then are added to the decay curve of Figure 1 offset to the right by time required for regulator contacts to close. The assumptions permitting the use of the single family of curves of Figure 2 to determine the restoration of flux are shown by close agreement with tests to be justifiable within the scope of the present article. Consideration of Figure 2 shows clearly that the following factors are important in the restoration of voltage: the corrected short-circuit time constant of the generator; exciter ceiling voltage; ratio of T_{d_1}'/T_e below values of eight or ten. The method can be applied with any type of voltage regulator for which the value of T_e governing the excitation voltage build-up can be determined.

Digest of paper 49-50, "A Semiempirical Approach to Voltage Dip (With Suddenly Applied Loads on A-C Generators)," recommended by the AIEE rotating machinery committee and approved by the AIEE technical program committee for presentation at the AIEE winter general meeting, New York, N. Y., January 31–February 4, 1949. Scheduled for publication in AIEE *TRANSACTIONS*, volume 68, 1949.

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Effective and Circuit Band Widths

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IN RECENT YEARS, the term "effective band width" has been used so frequently in the literature that it appears desirable to distinguish it from the more familiar band-width concept employed to specify the frequency discriminating properties of selective networks.

Despite the fact that electric networks may display the same maximum sensitivity and the same selectivity according to the customary definition, they nevertheless will display different sensitivities to noise. It is evident, therefore, that the results of noise measurements are meaningless unless accompanied by more adequate frequency-response data of the measuring instruments reduced to a common basis. The concept of effective band width, suitably defined, satisfies this requirement.

The term "circuit band width" then is reserved to specify the selectivity or frequency-discriminating properties of any given network.

The effective band width is an index of the network response to noise or other transient phenomena, the components of which are continuous and distributed throughout the frequency spectrum. For this reason, the effective band width is often referred to as the "noise" band width. The determination of the effective or "noise" band width of a network reduces to the problem of finding an equivalent rectangular response curve for the physical network. It is recognized readily that for the rectangular response curve there is little question as to the interpretation of band width, regardless of how arbitrary the definition might be in terms of relative response. The effective band width of any network of maximum response $A(f_0)$ is defined, therefore, as being numerically equal to the band width of an equivalent network whose response is $A(f_0)$ throughout the entire transmission band, provided the noise powers developed across the output terminals of the two networks are equal for the same noise signal input. Based on this definition, the analytical expression for the effective band width B becomes

$$B=\frac{\int_0^\infty A^2(f)df}{A^2(f_0)} \tag{1}$$

Equation 1 shows that the effective band width for any network is equal simply to the area under the squared response curve divided by the square of the maximum response. The area under the squared response curve plotted on linear co-ordinate paper may be determined by any convenient graphical or mechanical method. To obviate the necessity for converting the results of the mechanical integration into the dimensions indicated by equation 1, it is convenient to transform this expression for effective band width into a simple ratio of areas multiplied by some arbitrary unit of band width. Multiplying both the numerator and denominator of equation 1 by one kilocycle, this expression becomes

$$B=\frac{\text{Total area under squared response curve}}{\text{Area of 1-kc rectangle}}\text{ kc} \tag{2}$$

Thus the effective band width may be restated as being numerically equal in kilocycles to the ratio of total area under the squared response curve to the area of a rectangle one kilocycle wide whose ordinate is $A^2(f_0)$. Further simplification may be introduced by plotting the ordinates as squared response ratios $A^2(f)/A^2(f_0)$ rather than actual squared response, and the abscissa as the deviation from resonance $(f-f_0)$ in kilocycles rather than frequency.

It can be shown that for a single elementary inductive-capacitive resonant network, the ratio of the effective band width to the circuit band width (3-decibel attenuation) is equal to $\pi/2$, or 1.57 as illustrated in Figure 1. This ratio approaches 1.07 as the number of such isolated elementary stages arranged in cascade increases, and approaches unity as the response curve approaches the rectangular form.

The noise power developed across the output terminals of a network is a linear function of the effective band width only when dealing with noise phenomena uniformly distributed throughout the frequency spectrum, such as random noise, which is usually due to the spontaneous motion of free charge in electrical conductors. Noise phenomena of other distributions expressed in terms of average, effective, or quasi-peak voltage may be treated approximately by revising the exponent associated with the expression for effective band width. The magnitude of the new exponent will depend on the nature of the noise, that is, its frequency distribution, and the mode of measurement.

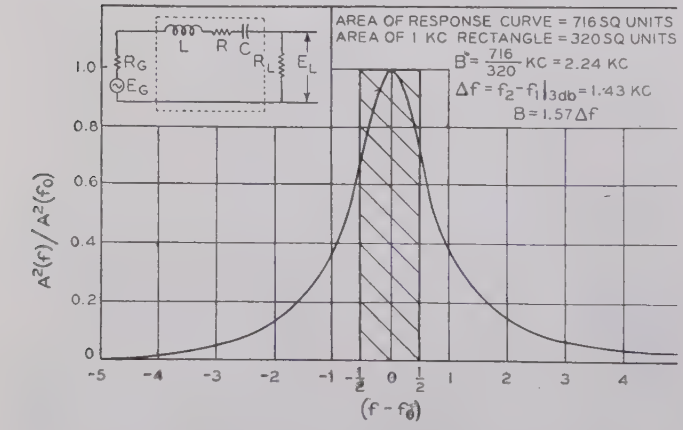

Figure 1. Squared response curve of physical network and 1-kc reference rectangle

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Digest of paper **49-26**, "The Distinction Between Effective and Circuit Band Widths," recommended by the AIEE communications committee and approved by the AIEE technical program committee for presentation at the AIEE winter general meeting, New York, N. Y., January 31–February 4, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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An Over-all Inspection Program

HENRY M. WOLFSON

The coil shops of the Western Electric Company have incorporated an over-all program for solving their inspection problems. Since their production includes various types of coils with many characteristics and requirements, different routines varying from little inspection to very detailed inspection are used.

THE HAVERHILL, Mass., shops of the Western Electric Company manufacture all the transformers, retard coils, repeating coils, and other similar coils, which are used in the assembly of equipment and subequipment at their Kearny, N. J., plant; also, a small portion of these components, likewise, is used at the Chicago, Ill., and Baltimore, Md., plants. These coils are manufactured practically from the raw materials, and the processes involved require inspections of all types: from raw materials inspection, through piece part inspection and process inspection, to inspection and testing of the final product. The diversified nature of the product and the quantities involved are such that the inspection procedures cover substantially every kind of such procedures normally utilized by manufacturers.

When the Haverhill shops were first set up in 1943, the quality of the product was not up to the desired level—as was to be expected with new and untrained personnel. At that time, a decision was required as to which of two courses management would follow. Would the course of expediency be followed and a final inspection and testing of the product be introduced merely to screen out the unsatisfactory production, or would the problem be approached by the more difficult method of concentrated training in the manufacturing processes to educate the operator to do it right the first time? Admittedly, the first course would result in immediate benefits from the standpoint of high-quality shipped products, but would be less apt to produce a satisfactory and economically manufactured product in the long run; while the second course would result in a less satisfactory, albeit acceptable, immediate product, but in the long run would produce an excellent product with a minimum of inspection and waste. Management's decision was to concentrate on the second course, keeping in mind that the quality of the shipped product must be maintained at a level satisfactory to the customer. To this end, the operators in the final inspection organization were given adequate training to assure that the product was screened adequately, but the greater portion of the training and engineering effort was applied to the manufacturing processes and procedures. The course selected paid tremendous dividends. The reduction in the cost of waste was startling, having been reduced from more than 12 per cent of the value of the shipped product to less than 6 per cent; the quality of the product as received by the final inspection organization improved from an average defective rate of more than 15 per cent to an average of approximately 3 per cent; and it was possible to reduce the cost of inspection through the introduction of sampling screens at appropriate points.

For the past two years, production at the Haverhill shops has averaged better than 50,000 coils per week. At first blush, this figure appears to be large enough to permit sampling inspection on the entire production. However, this weekly production was distributed over so many hundreds of types of coils with so many different characteristics and requirements, for which the quality level must be maintained so high, that the introduction of sampling was not quite as simple as it might appear. It was necessary, therefore, to analyze the entire manufacturing procedure from the raw material to the shipped product and introduce an integrated inspection program, each element of which was selected as the most suitable for the particular portion of the job to which it was applied. This program includes eight different routines varying from extremely little inspection percentagewise in some instances to 100 per cent detailed inspection in others.

The raw material and piece part inspection portion of the program presents the least difficulty; each problem as it develops falls into a standard inspection category. The raw material inspection is covered by standard specifications which list the tests to be made and, to a great extent, the size of sample. Raw material inspection, being generally destructive in character, is naturally restricted to small sampling. Further reductions in inspection are predicated upon experience factors with individual suppliers. Inspection of materials from some suppliers is made on every lot received, while materials from other suppliers may be accepted through inspection of alternate lots, or every third lot, or once during some specified elapsed period such as 30 days or three months. This merely applies, informally, the normal sampling theory which dictates more inspection for poor process averages and less inspection for good process averages.

The piece part inspection setup involves four different routines, namely:

1. Inspection by machine setup—a plan where the first few pieces produced are inspected individually to assure proper machine setup.

2. Multiple sampling, lot-by-lot on an AOQL (Average Outgoing Quality Limit) basis—a sampling plan of an indefinite number of successive samples which limits the average per cent defective in the product after inspection.

Full text of a conference paper presented at the AIEE winter general meeting, New York, N. Y., January 31–February 4, 1949.

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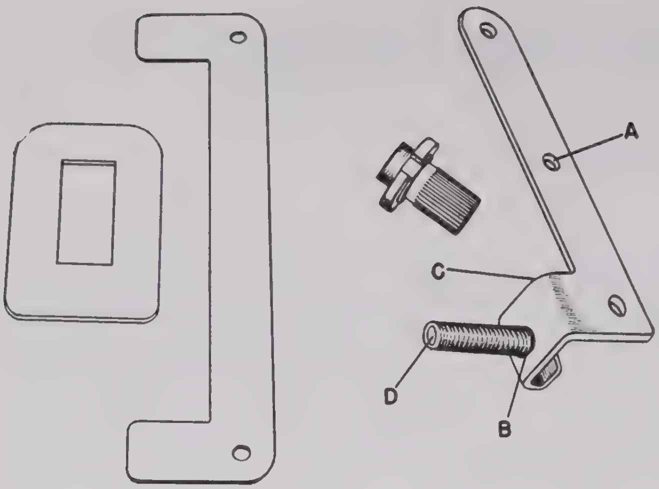

Figure 1. Two parts manufactured under closely controlled operation (left), and two parts manufactured by processes not as closely controlled (right)

3. Single and double sampling, lot-by-lot on an AOQL basis—a sampling plan of one or two samples which limits the average per cent defective in the product after inspection.

4. Lot-by-lot sampling on a lot tolerance basis—a sampling plan which limits the allowable per cent defective in an individual lot.

Many of the parts used are made under closely controlled conditions such as punch press operations in which, barring breakdown of the machine or tool, the last part produced differs materially from the first part only to the extent of wear on the tool. Figure 1 (left) illustrates two such parts; one, a spool head punched out of phenol fibre and, the other, a core lamination punched out of permalloy strip. A circulating inspector inspects the first pieces produced on all items of this nature and, if the parts meet their specifications, approval for the run is given. Thereafter, the inspector returns as often as experience dictates wear on the tool may develop. Otherwise, no further inspection is performed on these parts. If the setup or wear of the tool produces excessive burrs (on the metal part) or damaged edges (on the fibre part), changes in the tool, setup, or machine must be made before the run will be cleared.

Some parts used in the coil manufacturing processes are purchased from outside suppliers and are of the same type as those described in the foregoing, that is, manufactured under closely controlled conditions. In general, such parts are received either substantially entirely good or substantially entirely defective. Inasmuch as the consumer, the Western Electric Company, is not in a position to do any machine setup inspection under these conditions, a lot-by-lot multiple sampling plan[1] was selected as economical for parts manufactured under similarly controlled processes. The program setup, in general, provides an AOQL of two per cent. Inasmuch as all purchases are made to specification without allowance for defects, this program works no hardship on the supplier. On the other hand, the savings in inspection costs more than offset the losses resulting from the few defective parts which may be accepted.

Many of the parts produced at the plant or purchased from suppliers are manufactured under processes which are not as closely controlled as are punch press operations. Two such parts are illustrated in Figure 1 (right); one, a brass bushing made on a screw machine and, the other, a brass bracket. The bracket blank is punched out and is inspected by the machine setup routine. The blank contains the center hole *A* and the stud hole *B*. The other two holes are punched at a subsequent time because the spacing between them and the center hole varies with different types of coils. After the outer holes are punched, the bracket is bent as at *C*, the mounting stud *D* is inserted, and the bracket is formed over the stud head to hold the latter in place. Parts such as these are inspected by the standard double sampling methods, using the Dodge-Romig tables.[2] They are inspected to an AOQL of two per cent. Again no hardship is worked on the supplier, and the savings in inspection costs more than offset the losses resulting from the acceptance of a few defective parts. An AOQL of two per cent was selected as a result of an analysis of the control costs in our own piece part shop. On an average an AOQL of less than two per cent would require improved manufacturing methods which would be more costly than the total losses resulting from handling two per cent defective materials in later manufacturing stages. In other words, the breaking point between losses resulting from defects, on the one hand, and cost of maintaining a better process average, on the other hand, appears at approximately two per cent defective product. This is applicable only to the particular product involved. Other shops may find their breaking points quite different. Two questions may be raised in connection with the latter portion of the program:

1. Why are not variables or control chart inspection used for parts such as the bushing?

2. If that is not feasible, why is not multiple sampling used on all parts similar to those of Figure 1?

Variables inspection is not used because the quantities involved are too small. Only in rare instances do the required setups remain in use for more than a few hours, and in no instance is the process a continuous one. Under such conditions it would be extremely impracticable to administer a control chart method of controlling quality.

So far as multiple sampling is concerned, it is entirely possible that some future time may see the extension of this inspection procedure in the coil shop. For the time being, little advantage is seen in extending its application because of the cost and difficulty of administration and selection of successive samples; and in the meantime it is being limited to those products in which the cost of administration and selection of multiple samples is relatively low. In general, it is applied to those products, each of which is either practically zero per cent defective or practically 100 per cent defective, thus limiting the number of samples required.

Some of the parts manufactured in the shop are ordered by and shipped to other consumers. Since the large majority of these are ordered in small quantities and at infrequent intervals, parts leaving the Haverhill shops are reinspected to a lot tolerance of one per cent. Operating characteristics of coils are determined by two procedures:

1. By means of special adjustment.
2. As a result of basic design and construction.

This creates two distinct approaches to the problem of inspection at various stages of partial completion of the product. In the case of the first classification, no process inspection of the individual units is required; the adjustment within defined engineering limits should produce the desired characteristics. That portion of the product which falls into the second classification either is inspected at some stage of partial completion, or not, dependent upon the relation between the cost of inspection of the entire output and the cost of further processing to completion and final inspection of such defective units as normally are produced by the specified procedures. The relation between these two costs assigns this portion of the product to one of the two following subclasses:

(*a*). The cost of further processing to final inspection of the anticipated defects is less than the cost of 100 per cent inspection. These coils are not inspected or tested in process for the particular characteristic at all.

(*b*). The cost of further processing to final inspection of the anticipated defects is more than the cost of 100 per cent inspection. These coils are tested in process individually.

It is to be noted that the coils are assigned to one or the other of these two subclasses as a result of the per cent defectiveness "anticipated." This dictates a reasonable control over the manufacturing processes to produce the "anticipated" product. In addition to the operator's self-verification and supervisor's checks, a circulating inspector in each department of the plant spot-checks all processes to assure as close adherence to specified procedures as possible.

By far, the greatest amount of difficulty in the development of the over-all inspection program is presented by the final electrical requirements of the product. Although the quality of the coils delivered for final inspection is relatively high, it is, on an average, poorer than the quality which is considered acceptable for the customer or user. Furthermore, the product is so diversified in nature that the size of lot as delivered to inspection is much too small to permit inspection cost reduction through the application of standard sampling methods.

Figure 2 is a cumulative frequency curve of the distribution of lot sizes. It is readily seen that more than half the product is handled in lots of 40 or less, and more than 90 per cent in lots of 100 or less. For an AOQL of 0.20 per cent, which is just about all that can be tolerated, most sampling methods require substantially detailed inspection for the lot sizes indicated. It obviously is not possible to effect any economies through lot-by-lot sampling inspection, so that it is necessary to consider some means of circumventing the restrictions imposed by the diversified nature of the product.

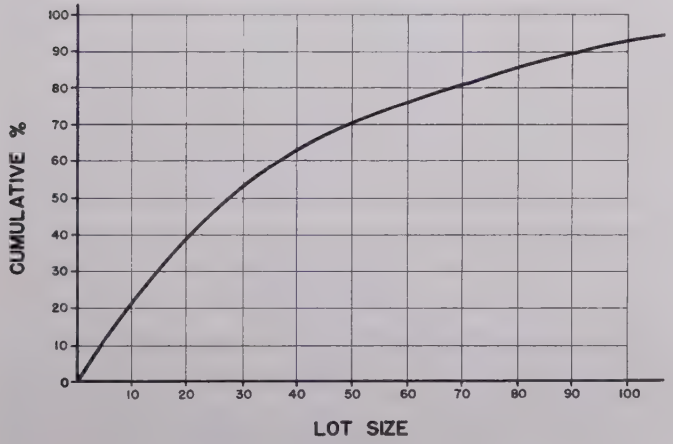

Figure 2. Cumulative frequency curve of distribution of lot sizes

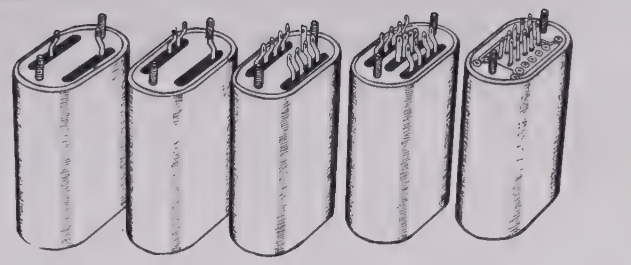

Figure 3. Coils of the same type, but which have different electrical characteristics, are combined as one lot for purposes of assembly and inspection

It is readily apparent that so long as the products are coils of numerous types, the difficulty would persist in the analyses being made. However, if the product were analyzed on the basis of coil characteristics, some means might be developed to permit savings by statistical control.

In general, the product can be subdivided by electrical characteristics into three groups:

(*a*). Characteristics which do not distribute normally about some point of central tendency, particularly as to defects. Examples are

1. Defects resulting from the omission of electrostatic shields between windings or from broken lead wires from such shields.
2. Defects resulting from failure to impregnate coils or from improper impregnation.

(*b*). Characteristics which distribute normally about some point of central tendency and which result substantially entirely from rigidly controlled processes.

(*c*). Characteristics which would distribute normally about some point of central tendency but in the adjustment for which the human element enters to a substantial extent.

Assurance of satisfactory quality in the case of groups *a* and *c* can be obtained only through lot-by-lot inspection, either detailed or sampling, depending upon the process average and lot size. As already stated, the lot sizes by types of coils are relatively small and sampling inspection ordinarily would not be economical. However, there are characteristics which are common to many types, so that many coils may be produced in families of one type by a single process; the inspection of these families can be combined, thus making the lot sizes rather large. For instance, all the coils shown in Figure 3 are different; however, they are all of similiar structure; they are impregnated in the same equipment, by the same process, and often simultaneously; and they are potted in the same production line, with the same materials, and the same equipment. All of these coils can be combined as one lot for the purpose of inspection for insulation resistance. Likewise, they are wound on the same machines, assembled in the same production line, and handled throughout as one product. Each of these families runs at the rate of approximately 3,000 per week and the process average is substantially zero.

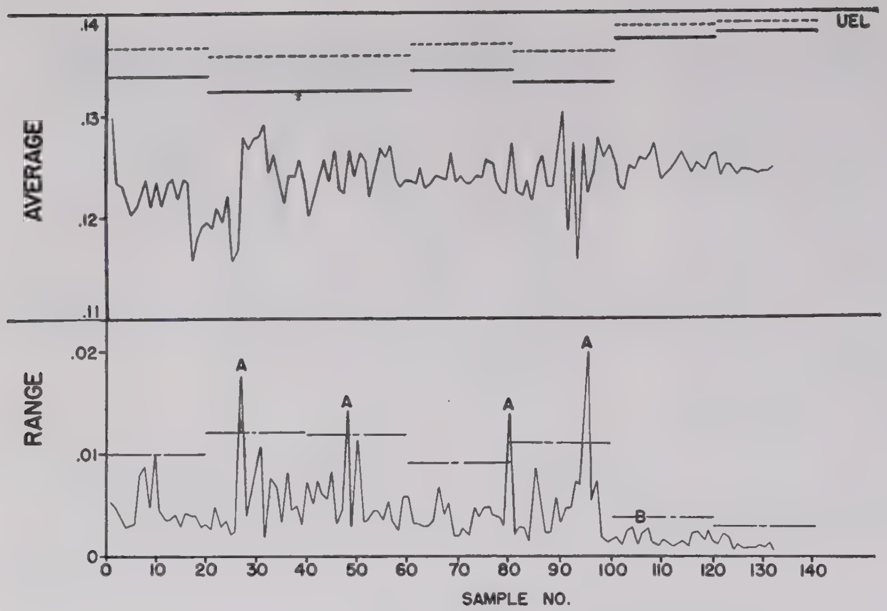

Figure 4. A control chart, set up as an acceptance criterion, is used in the coil shop

– – – *Production average limit* ——— *Conformance-control limit* — – — *Range control line*

They are sample inspected to an AOQL of 0.1 per cent and the saving in inspection time is substantial.

So far as group *b* is concerned, the nature of the manufacturing process permits variables inspection wherever the particular process results in a product with a good process average. So long as the process remains under proper control the output will be distributed within the limitations developed for the control lines. Figure 4 is a reproduction of the control chart used for the first two years of production of one type of coil under the sampling scheme.

This type of inspection is introduced in two distinct steps. The first covers the introduction of process quality control by the control chart method in accordance with well-established principles. This is done to determine how closely the manufacturing process can be controlled without excessive expenditures, and what action must be taken if any to effect such control. After this has been done and it has been determined that the constant system of chance causes will produce a satisfactory product, the modified control chart (Figure 4), set up as an acceptance criterion, is introduced. This type of chart is ordinarily referred to in the Bell System as a conformance-control chart and is introduced in the coil shop when the process average is well within the engineering limit. The conformance-control limits usually are set at a value equal to 3σ-$3\sigma/\sqrt{n}$ inside the UEL (Upper Engineering Limits). The acceptable level for the product average is located 3σ inside the UEL. These "modified" limits are similar to those of E. H. Sealy in his guide to quality control,[3] except that the latter are placed at a value equal to 3.09σ–$1.96\sigma/\sqrt{n}$ inside the UEL.

It is interesting to note that the process of Figure 4 is maintained at a level so far within engineering limits that considerable excess in the range would be permissible before any serious difficulty would be anticipated. This permitted the introduction of a test fixture which could at times introduce some variation and result in a range beyond the control line. Such points are shown at *A* of Figure 4. Investigation on each of the occasions, when the range control line was exceeded, indicated that the fixture was the cause and the product was satisfactory. Some changes in the fixture were made to reduce the variable condition and the improved results are reflected in the control lines beyond point *B*. Under normal conditions variables or control chart inspection is applied where a process is continuous or semicontinuous. A prerequisite of this method is constancy of manufacturing conditions and such constancy is most readily attained in a continuous process. The coils represented by the curves in Figure 4 are manufactured under such conditions, and it was readily apparent that this particular item could be inspected by variables in view of its good process average.

Application to other items is approached cautiously since manufacture is intermittent, although fairly periodic. In each case, the manufacturing setup is destroyed and reset each time production of a coil is discontinued. Extensive investigations are made paralleling detailed inspection with variables inspection to determine the effect of such intermittent setups; it is found that whenever the setup is incorrect, entire lots are affected and the results are reflected in the variables inspection providing some portion of each lot is inspected. Time analyses on numerous coils disclose that, on an average, variables inspection on the basis of a sample of five coils took as long as the inspection by attributes of 40 coils. Hence, all lots of more than 40 coils could be inspected by variables with a resultant saving if the process is under adequate control. Approximately 35 per cent of the product is produced in lots of 40 units or more; this field was, and is being, combed for items to which variables inspection can be applied. The variables inspection setup calls for a sample of five units for all lots up to 100 units, two samples of five each for lots from 101 to 250, three samples of five each for lots from 251 to 500, and four samples of five each for all lots of more than 500.

The foregoing program is by no means the ultimate. The ultimate never may be attained, for analyses are being made continuously with a view to improvement of the program, always pointing toward the reduction of inspection costs and the maintenance of high quality.

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Equipment for Turbine-Electric Locomotives

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THE ELECTRIC transmission equipment used on the three turbine-electric locomotives placed in service in 1948 by the Chesapeake and Ohio Railway Company is similar in many respects to that used on diesel-electric locomotives of equal power. The differences are principally in the main generators and the control. These differences are due to 6,000 horsepower being supplied by a single prime mover and the difference in fundamental speed and torque performance of a steam turbine as compared to a diesel engine. A comparison of fundamental characteristics, Figure 1, shows that the turbine torque rises rapidly as speed decreases and that its horsepower is much more constant from full speed to "idling" speed. In the case of diesel-electric, considerable development of generator control devices has been necessary to prevent overloading.

The generator armature arrangement used was determined by a combination of mechanical, commutation, ventilation, motor-grouping, and space requirements. Two d-c double-armature generators, direct-connected to two gears driven by the turbine-shaft pinion, proved to be an advantageous arrangement for meeting these requirements. A six-to-one gear reduction is used to obtain an armature speed of 1,000 rpm. Each of the four armatures supplies power to two standard axle-hung traction motors in parallel. Both generators and motors are force-ventilated from blowers driven by auxiliary turbines.

The steam turbine has a torque characteristic that rises as speed decreases. This, together with the high flywheel effect of the power plant, allows the use of simplified load control of the generators as compared to that required for diesel-electric locomotives. The generators are of the self-excited type with a small amount of separate excitation from a small constant-voltage auxiliary generator. The latter also supplies other low-voltage locomotive requirements, such as the indicator lights, control circuits, lubricator pump, and air-brake system.

When the locomotive is ready to start, the turbine is idling at 63 per cent speed (3,780 rpm) and the generators are running at 630 rpm. This relatively high idling speed requiries control provision for obtaining a smooth application of power. Manipulation of the turbine speed is not sufficient by itself; therefore, field control of the separately excited fields of the generators is used. These fields are gradually increased in 11 steps (master controller notches) by reducing an external resistance that affects all four fields equally. The turbine speed is increased slightly also from the 6th to the 11th notches so that the generator rpm is 750 on the 11th notch. These field notches are gradual enough to insure an exceptionally smooth locomotive start under all conditions of grade or train tonnage.

The master controller, besides providing contacts for operating the contactors for the generator-field notches, also controls the speed setting of the turbine governor. This is done by a cam on the controller shaft which varies the setting of an air pressure system connected to the governor arm. Since no control batteries are used on these locomotives, a second cam on the controller actuates an air valve which permits bringing the turbine up to idling speed without control power being available. An "idle" position is provided between "off" and "on" positions. Steam is admitted to the turbine on this notch and the motor switches are closed, but no excitation is applied to the generators. A stop is provided so that the handle is stopped in the "idle" position on a normal shut off. To move the handle to the "off" position and stop the turbine, a button in the end of the handle must be pressed.

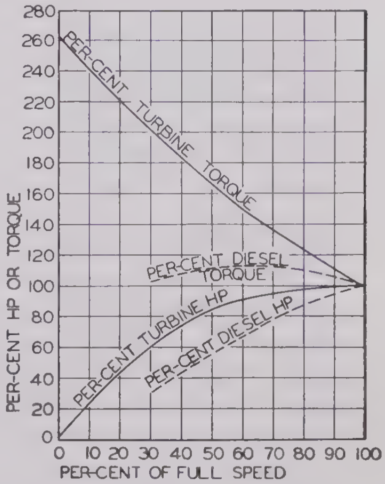

Figure 1. Comparison of speed, horsepower, and torque at full throttle — steam turbine and diesel engines

Overload protection of the electric equipment is accomplished by relays that are arranged to de-energize the emergency trip valve, thus shutting down the turbine without interrupting the load current. Overspeeding of the turbine is prevented by an overspeed device on the main shaft as well as by the governor, but, in addition, the control insures against sudden removal of load. Other protections are provided in the form of wheel slip indication and a phantom ground indicator connected midway between positive and negative busses of each generator circuit.

The electric equipment for these locomotives employs generators, motors, and control designed on proved electrical and mechanical principles. The special requirements imposed by the prime mover and locomotive arrangement have been met with a simplicity of components that compares favorably with types using electric transmission.

Digest of paper 49-45, "Electric Equipment for Chesapeake and Ohio Railway Steam Turbine-Electric Locomotives," recommended by the AIEE land transportation committee and approved by the AIEE technical program committee for presentation at the AIEE winter general meeting, New York, N. Y., January 31–February 4, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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D-C Reactors With Resistive Load

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THE IMPEDANCE of an iron-core reactor can be varied by introducing a magnetic bias whose magnitude is controlled by a direct current in a separate control winding. Such d-c controlled reactors commonly are called saturable reactors or magnetic amplifiers.

When a saturable reactor is connected to a load, an increase in the current in the d-c winding will increase the magnetic bias in the iron core. This will shift the alternating magnetic flux to a region of higher saturation and hence decrease the impedance of the a-c winding. If the load consists of a resistance, a change in the direct current and hence in control power is associated with a change in the load power. It will be found that a certain change in output power can be achieved with a much smaller change of input power; hence the term magnetic amplifer. Although it competes with the electronic amplifier, the magnetic type cannot be applied to frequencies of 100 kc or more.

In order to prevent voltages of fundamental frequency from being induced in the control winding, the a-c load winding usually is divided into two halves which are mounted on separate legs of the core. These reactors are called parallel or series reactors, depending on whether the a-c windings are electrically connected in parallel or in series.

The performance of the two types of reactors is different in several respects. Whereas in both instances the load current contains harmonics of odd order only, the a-c coils of the parallel reactor also may carry currents of even order. Even harmonics are also present in the control winding. Increasing the resistance in the control winding of a parallel reactor is very effective in reducing the even harmonics in the control winding, and simultaneously increasing the even harmonics in the a-c winding. In the case of a series reactor it is difficult to suppress the even harmonics; this fact is utilized in frequency doublers.

The speed of response of the impedance to a variation in the control current is different in both types of reactors. If the control current is varied in a series reactor, the flux will change almost simultaneously, and so will the impedance. By placing a forcing resistor in series with the control winding, the response to a variation of the control voltage can be greatly increased, and hence the impedance of the series reactor can be made to follow rapidly the changes of the control voltage. Harmonic voltages of even order will be observed across the forcing resistor, which may cause concern because of their magnitude. In case of a parallel reactor, any change of control current causes transient currents to flow in the a-c winding which oppose the change of control current. As a result, the flux in the core will change at a slower rate, that is, with a time constant approximately equal to the sum of the time constants of the control winding and the a-c windings. Hence, a forcing resistor in the control winding will have only a limited effect in increasing the speed of response. See Figure 1.

If direct current is applied to the control winding while the a-c circuit is open, a constant flux, Φ_0, called quiescent flux, will exist in the core. If the control circuit is left unchanged and the a-c circuit is closed, varying flux will be observed in the core. When this varying flux is analyzed, it will be found that its constant component Φ_{dc} is not equal to the quiescent flux Φ_0, but smaller. Generally, any change in load current will change the average value of the flux. The control winding is linked with this flux and hence transients will occur in the control winding; for an increase in load current, the transient is in the same direction as the steady-state control current and vice versa.

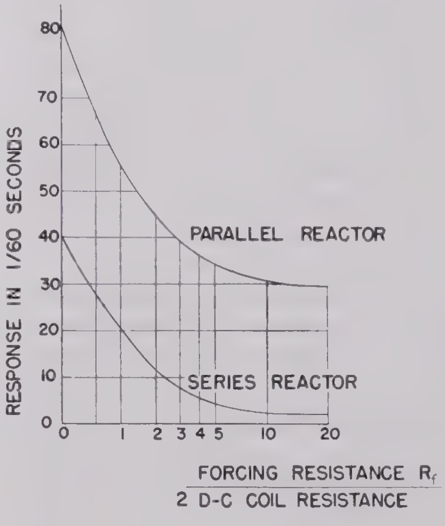

Figure 1. Transient response of parallel and series reactors

This shift of Φ_{dc} also causes a change of impedance. If, for instance, the a-c circuit is closed at the phase angle where the alternating current is zero during steady state, no switching transients would be expected ordinarily. Actually, however, it will be observed that the alternating current will be much larger at first and gradually decays to its steady-state magnitude. The explanation lies in the fact that the impedance is smallest for the quiescent flux. Under the effect of alternating current, the average value of flux decreases, causing an increase in impedance. If the a-c switching occurs at a different phase angle, further transients will be observed; these transients contain d-c components in the a-c circuit and are similar to switching transients in a-c circuits which do not contain a d-c control circuit.

Digest of paper **49-55**, "Some Fundamentals of D-C Controlled Reactors With Resistive Load," recommended by the AIEE transformer committee and approved by the AIEE technical program committee for presentation at the AIEE winter general meeting, New York, N. Y., January 31–February 4, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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The Renaissance of Electric Motive Power

A. H. CANDEE

Characteristics of locomotive electric equipment were thought to be well established, but development of self-propelled electric locomotives has introduced new concepts. Design improvements have reduced equipment size, improved reliability, and promoted a degree of standardization heretofore thought impractical. Electric motive power leads the way toward improved rail transportation.

THE DESIGN CHARACTERISTICS of the electric propulsion equipment of electric locomotives were thought to be well established by the development and use throughout the last half century of the trolley-electric or third rail-electric locomotives which receive power from an external source. However, the widespread application of self-propelled electric locomotives and railcars over the past 23 years and particularly the increased use of diesel-electric locomotives (which have, within the past 12 years, threatened the existence of self-propelled steam locomotives) have developed new concepts as to the design, arrangement, capacity, limitations, and advantages of electric propulsion apparatus for railroad motive power.

Any locomotive whose propulsion is effected by means of electric motors mounted on it is an electric locomotive, whether the propulsion power is generated elsewhere and transmitted to the vehicle, or whether it is generated on the locomotive itself. This term, then, is generic and embraces the trolley- or third rail-electric, the gasoline-electric, the diesel-electric, the steam turbine-electric, the gas turbine-electric, and the storage battery-electric locomotive.

During early stages of development, several builders of diesel-electric locomotives purposely deleted the term "electric," claiming that the electric equipment was merely a transmission system and of secondary importance to the diesel engine, being a convenient but not entirely necessary accessory. Subsequent experience, however, has shown that many of the desirable operating characteristics of this type of motive power are directly attributable to the electric propulsion system, and that these same features are inherent in the steam turbine-electric locomotive, the gas turbine-electric locomotive, or any other self-propelled vehicle having electric drive.

TRACTIVE FORCE IMPROVED BY ELECTRIC DRIVE

Many railroad men have been astonished by the ability of a relatively low-powered diesel-electric locomotive to outperform a high-powered (peak) reciprocating steam locomotive. The explanation of this may be found, in part, to be on account of the tractive force characteristics of the electric system of power transmission and propulsion as used with the diesel-electric motive power, and which are available for any type of self-propelled motive power if electric drive is used.

In any properly designed electric drive, three characteristics are outstanding:

1. *High Tractive Force for Starting a Train.* The complication involved in driving the wheels of a self-propelled locomotive by mechanical means from a prime mover normally limits the number of wheels (or axles) that may be driven. Very few modern steam locomotives have more than four pairs of wheels (four axles) driven by a single prime mover, because such axles must be contained by a rigid frame and more axles make the rigid wheelbase too long for sharp track curvatures. In order to get high starting tractive force, then, the weight on this small number of driving axles must be high (if normal values of adhesion are considered), which is often impractical. This limitation is not present with electric drives, because traction motors may be applied to as many driving axles as may be found expedient. Therefore, an electrically propelled locomotive may have vastly improved starting characteristics over any type of mechanical drive and yet stay within reasonable weights per axle and adhesive factors.

2. *High Available Power at Low Train Speeds.* The power developed by a prime mover is a function of its speed. In any mechanical drive system, the speed of the prime mover and of the vehicle are directly related, so that full power is developed only at that vehicle speed corresponding to the full prime mover speed. With a fixed relation between them, it is obvious that over the lower ranges of vehicle speed, only partial power can be obtained. In this respect, a self-propelled vehicle with an electric drive has a definite advantage. Since there is no mechanical connection between the prime mover and the drive wheels, the prime mover may be operated at its full speed and power at any locomotive speed. During acceleration of a train or when negotiating severe grades, this feature is of considerable value in improving scheduled train speeds. Figure 1 illustrates the comparative speed-tractive force-horsepower characteristics of a conventional steam locomotive and those of a self-propelled electric locomotive.

3. *Development of a Smooth, Nonpulsating Tractive Force.* One characteristic of an electric traction motor is that its

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Essential substance of paper 49-44, "The Renaissance of Electric Motive Power," recommended by the AIEE land transportation committee and approved by the AIEE technical program committee for presentation at the AIEE winter general meeting, New York, N. Y., January 31–February 4, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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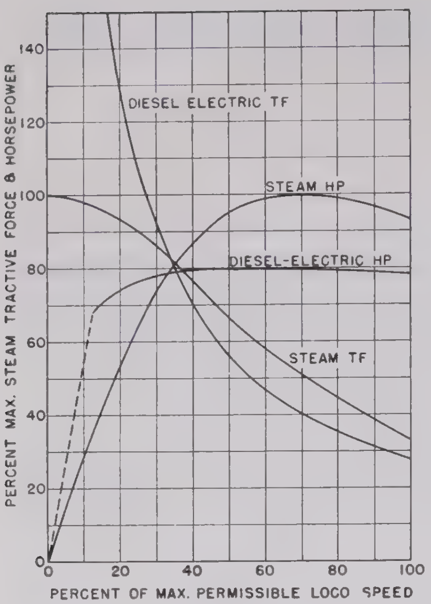


Figure 1. Comparison of locomotive characteristics: reciprocating steam—4,250 horsepower at driver rims; 4,000 horsepower diesel-electric — 3,350 horsepower at driver rims

torque (tractive force) is of a continuous nature, without periodic variations or pulsation. In contrast the tractive force of a reciprocating steam locomotive, especially at low speeds, is extremely variable (Figure 2). With such a locomotive designed for an average tractive force corresponding to a 25 per cent adhesive factor, the peak tractive force which occurs once each wheel revolution corresponds to an adhesive factor in excess of 30 per cent when starting a train. Since it is this peak force which determines the slipping point of the wheels, it follows that if a reciprocating steam locomotive does not slip at an average of 25 per cent adhesion (peak above 30 per cent), a locomotive with an electric drive will not slip at a tractive force corresponding to 30 per cent adhesion, and because of the continuous character of the force, this value may be maintained. By virtue of this, heavier trains may be started and handled much more easily than with a mechanical drive.

Most railroad motive power men base their estimate of the worth of a locomotive on its tractive force characteristics rather than on its power. This is because, with a reasonable power output obtainable, high tractive forces for train starting and acceleration are of more importance than high power which can be developed only when operating at high train speed. This is one reason why the diesel-electric locomotive, with its electric drive, has found favor among the operators of this type of power.

INDEPENDENCE OF PRIME MOVER

The use of an electric system of power transmission has contributed greatly to the success of the internal combustion engine (particularly the diesel engine) as a prime mover for locomotives and railcars. Since the engine drives a generator for the conversion of its power into electric energy and is, therefore, independent of any mechanical relation to the driving wheels, this engine with its generator may be mounted in the most suitable location for accessibility and weight distribution. Placing the power plant in a position where it may be readily inspected and repaired is conducive to its ready maintenance as an effective source of power with a minimum risk of failure in service.

It is the present practice to design the automatic loading characteristics of an electric transmission system so that full torque will not be demanded of the prime mover until it approaches its full load speed. This materially reduces engine stresses as compared with mechanical drives, and promotes long life as well as a reduction in repair expense. This electrical feature is often considered to be one of the contributing factors to the success of the diesel-powered electric locomotive.

FUTURE OF ELECTRIC TRANSMISSION SYSTEMS

Railroad motive power is undergoing a metamorphosis. For nearly a hundred years the accepted type of power unit was the reciprocating steam locomotive. Then, the gasoline-engined railcar entered the field, inevitably followed by the diesel-electric railcar and locomotive, which rapidly are replacing reciprocating steam power. Other locomotives have been built, or are under consideration, including steam turbine units operating at conventional locomotive boiler pressures and with mechanical or electric drive, a steam turbine-electric locomotive obtaining its steam from a new high-pressure boiler, and a gas turbine-electric locomotive. Because the advantages of electric drive now are recognized, it is predicted that locomotives of the future, other than the reciprocating steam type, will be built with electric drive.

BASIC TYPE OF ELECTRIC TRANSMISSION EQUIPMENT

The primary requirement of an electric power transmission system, as used for railroad locomotives and railcars, is the ability to convert the power available for propulsion into any desired speed-tractive force combination necessary for the locomotion of the vehicle. Since horsepower is the product of the pounds of tractive force and speed (miles per hour) divided by 375, it follows that in any type of locomotive with a fixed maximum prime mover horsepower capacity, the speed of a locomotive changes in inverse relation to the tractive force requirement. Thus, the negotiation of a severe grade is always at relatively low speed, and high speeds are attained only when the resistance to train movement is reduced. Since the varying character of a railroad profile requires continual changes in the speed-tractive force values, it is obvious that any electric drive system should permit an infinite variation in such relationship throughout the locomotive operating range, from the maximum tractive force required for train starting and acceleration to the maximum permissible locomotive speed.

D-c electric machinery is naturally adaptable to the variable requirements of self-propelled locomotives. By the use of a d-c generator (having means for varying its field strength) and series-type traction motors, variable values of speed and tractive force may be obtained in a very simple manner. As against this, nearly all of the simple and efficient a-c motors obtain their major speed variations through a change in pole combinations or in frequency of electric alternations. Since the generated frequency is a function of the prime mover speed, and since it is necessary to operate the prime mover at constant speed for obtaining its full power, any a-c system of locomotive power transmission becomes very complicated if variable frequency (and thus locomotive speed) is obtained. In the case of the electric locomotive receiving its power through a trolley wire from a single-phase a-c power supply, the disadvantage of a commutator-type a-c traction motor (which is a variable speed a-c motor) is accepted for the advantages of the a-c distribution system.

In a d-c system, tractive force is related to the current flow through the traction motors, and speed is related to the voltage impressed across the motors. Since electric power is a product of volts and amperes and since the current flow through a traction motor increases as it slows down (as caused by an increase in track grade) and vice-versa, it is only necessary to adjust the voltage of the generator in inverse relationship to the current flow in order to maintain constant power demand from the prime mover. The simplicity of this equipment and the ease of its regulation has resulted in a vast expansion in the use of d-c apparatus and practically has insured the continued use of this system for railroad self-propelled electric vehicles.

NUMBER OF TRACTION MOTORS PER LOCOMOTIVE

As has been mentioned, high axle loading has been the customary practice in reciprocating steam locomotive design, where the limited number of driving axles make it difficult to obtain high-starting tractive force. The use of electric drive, however, has allowed still higher tractive forces to be obtained with low axle loadings and, as a result, many motive power men are giving careful consideration to the idea of reducing the load on individual pairs of wheels with any type of power.

While some railroads do not hesitate to apply axle loads up to 70,000 pounds, there are many others that have lighter rails and poorer roadbed and must, perforce, limit their loadings to a figure between 50,000 and 55,000 pounds per axle, or even lower. Furthermore, investigations have shown that there is a tendency for rail head shatter cracks to be propogated into complete rail fissures above certain speeds for different axle loadings:

Worn Wheel* Diameter (Inches)	Axle Load (Pounds)	Approximate Speed Limit (Miles Per Hour)
36	50,000	90
36	55,000	72
36	60,000	56
36	65,000	42
38	50,000	105
38	55,000	85
38	60,000	67
38	65,000	52
40	50,000	120
40	55,000	98
40	60,000	78
40	65,000	62

* These wheel diameters are within the sizes used for self-propelled electric locomotives

This further illustrates the desirability of low axle loadings in the interest of reduced rail failures. It is, of course, not always possible to keep to these low limits, but the figures serve as a goal toward which to strive.

It is apparent that low weight per driving axle may necessitate a large number of driven axles if high-starting tractive force values are to be utilized at reasonable coefficients of adhesion between the wheels and the rail. It has been found that the practical starting tractive force values for the various types of railroad service are

Switching	50 to 65 pounds starting force per prime mover horsepower
Passenger	20 to 25 pounds starting force per prime mover horsepower
Freight	35 to 45 pounds starting force per prime mover horsepower

The preferred number of driven axles, then, may be calculated from these factors:

$$\text{Number of axles} = \frac{\text{Starting pounds per horsepower} \times \text{prime mover horsepower}}{\text{Allowable pounds per axle} \times \text{selected adhesive factor at start}}$$

Thus, for freight service, eight motored axles are desirable for a 3,000-horsepower diesel-electric locomotive with a 55,000-pound axle loading and an allowable adhesive factor of 25 per cent, as follows:

$$\text{Number of axles} = \frac{35 \times 3000}{55{,}000 \times 0.25} = 7.65, \text{ or } 8$$

Because of the electrical groupings of traction motors fed from a single generator, it is expedient at present to select the number of motors as a multiple of four or six. Diesel-electric locomotives are now available with 4, 6, 8, 12, 16, and 18 traction motors. In small sizes, one or two traction motors are sometimes sufficient.

ELECTRICAL RATINGS

The use of an electric transmission system introduces a time factor into the application and use of self-propelled motive power which is not readily understood by the operating forces of a railroad that have been used to steam power with mechanical drive. This time factor is occasioned by electric heating of generators and traction motors.

Electric rotating apparatus rating is based upon the current which can be carried continuously (at a specified voltage) without exceeding the safe temperatures established for its type of construction. This continuous current value is normally converted into a continuous tractive force rating, and operation at a tractive force in excess of the rating will cause, if continued, the electric equipment temperature to exceed the established safe limit. How-

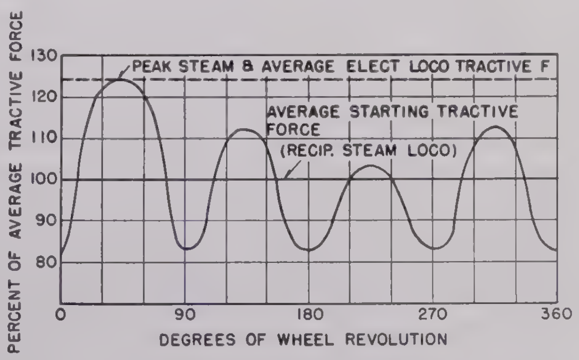


Figure 2. Tractive force variation per wheel revolution of a reciprocating steam locomotive

Electric locomotive can maintain 24 per cent higher tractive force than steam without exceeding steam locomotive adhesive limits ever, if this overload tractive force is applied with the electric motors and generators at reduced temperatures, time elapses before the equipment reaches its maximum allowable temperature. It is these permissible overload ratings based upon time limits which confuse the average operating man.

The time factor is not a fundamental limitation of electric motive power, but is the result of commercial expediency. It is obvious that if large enough electric motors and generators were applied to give a continuous tractive force rating to exceed the maximum that ever could be exerted (or equivalent to 40 per cent adhesion between the wheels and rails), then no operating condition ever could arise which would overheat the equipment. This would require extremely large, heavy, and expensive electric machinery. In this age of modern self-propelled electric locomotives, competition makes it necessary to use smaller motors and generators than the ideal size in the interest of reduced equipment cost, and by so doing forces the limitations in tonnage hauling capacity.

In reducing the capacity of electric machines from a size which will not overheat to that which is commercially practical, considerable judgment must be exercised and the results of actual operation analyzed. Unlike trolley-electric motive power, where schedules, grades, and tonnages are rather well defined, the self-propelled locomotive must be built to fit an extremely wide range of operating conditions. Experience has shown that the practical minimums for the continuous tractive force ratings of the electric equipment should be for the following services:

Switching	13 to 15 per cent of the weight on drivers
High-speed passenger	11 to 12 per cent of the weight on drivers
Medium-speed passenger	15 to 16 per cent of the weight on drivers
Low-speed passenger	17 to 18 per cent of the weight on drivers
High-speed freight	14 to 15 per cent of the weight on drivers
Medium-speed freight	17 to 18 per cent of the weight on drivers
Drag freight or transfers	20 to 22 per cent of the weight on drivers

For greatest utility, an electric locomotive must be given as high a tonnage-hauling rating as possible within the safe temperature limits of the electric motors and generators. The maximum tonnage rating of a mechanically driven locomotive for any section of a railroad is that load which can be hauled over the worst grade of that section without stalling. If this tonnage is exceeded and the train stalls, no harm is done to the motive power. This method of rating is not practicable when electric drive is used, for tractive force values considerably in excess of the continuous rating may be developed without stalling, and correspondingly high ultimate temperature of the electric machinery may be reached. Thus, to determine the maximum tonnage rating of an electric locomotive, calculations or a test must be made to find the peak electric equipment temperatures when negotiating the worst grades. Such calculations may involve short-time ratings.

Short-time ratings of electric locomotives must be applied with great care in establishing the tonnage-hauling capacity of a locomotive. Even though ample margins are allowed to insure safe temperatures of equipment under ordinary operating conditions, there are many unforeseen circumstances which may require more tractive force than estimated and thus increase the heating beyond safe limits, such as dragging train brakes, inaccurate estimate of train weight, excess proportion of high-resistance cars in the train, or deliberate overloading by uninstructed personnel. Where short-time ratings must be employed to keep within temperature limits, there is always considerable risk of exceeding these if anything goes wrong. For this reason, it is much safer to establish tonnage hauling ratings for the longer grade zones upon the basis of the continuous tractive force rating rather than on short time values. Actual experience has shown that this results in increased operating reliability and reduced electrical repair expense.

ELECTRICAL LOADING OF PRIME MOVERS

In the foregoing, a number of factors involved in the design of the self-propelled electric locomotive have been discussed, including the main electrical components, the number of traction motors, the method of driving axles, and the traction motor capacity. Another very essential element to the success of this type of power is the system of control by means of which full advantage may be taken of all of the power available, whenever it becomes desirable to do so, yet at the same time which limits this load to the capabilities of the prime mover.

One of the important characteristics of a trolley-electric (or third rail-electric) locomotive is the possible utilization of relatively unlimited amount of power for propulsion purpose. In any self-propelled unit, the prime mover has a maximum output, usually varying somewhat with the mechanical condition of the plant and with atmospheric changes. Since this power is limited and is usually far below that which could be effectively utilized for propulsion, it is essential that the full available capacity of the prime mover be obtained when needed, whatever its output may be. Moreover, the determination of how much power the prime mover can develop safely should be automatic and not require judgment by the operator.

Various types of power plants—the gasoline engine, the diesel engine, the steam boiler and steam turbine, and the gas turbine—have different limitations to their maximum capacity. The effect of an overload on a gasoline engine is to reduce its speed but not necessarily to stall it, whereas such an overload on a diesel engine usually will stall it (assuming constant safe maximum fuel input). The steam turbine, however, is not harmed when reasonable overloads are applied; and with a limited amount of excess energy stored in the steam boiler, such plants are capable of delivering more than their rated output for a short length of time without harmful effect. Gas turbine plants, being limited by gas temperature and blade materials, probably will not be given any overload factor until experience shows that overload ratings are permissible. Atmospheric conditions, however, effect big changes in its power output.

Automatic load regulation has attained its highest development in connection with diesel-electric motive power. An essential of any such control system is simplicity, since adjustments often are made or equipment repaired by railroad personnel who are not trained electrical engineers. It generally has been found expedient to use the engine governor position as an indication of engine loading conditions, since a tendency to admit more than full fuel means an overload and action to reduce the fuel below the maximum allowable indicates an underload. Using the governor to initiate action of the load control system eliminates an extra device for this purpose and promotes simplicity. Full output of the engine is assured also, since the governor action always compares the full capability of the engine against the applied electric load. Such a load control system acts to vary the field strength of the main generator until the volt-ampere output of the generator corresponds to the power input.

In general, internal combustion engines should not be loaded to full torque at reduced engine speeds. Almost all modern control systems for diesel-electric motive power take cognizance of this, applying electric load at very low torque at engine idling speed and gradually building up to full torque only when the engine reaches the range of its full operating speed. This is illustrated by Figure 3.

TRACTION MOTOR CONNECTIONS

No comment need be made on the use of the series-type traction motors for railroad propulsion, because it is well known that their self-adjusting characteristics make them ideal for meeting the extremely variable tractive force requirements of such service. However, the method of connecting them electrically to the source of power has a direct bearing on the operation of the locomotive.

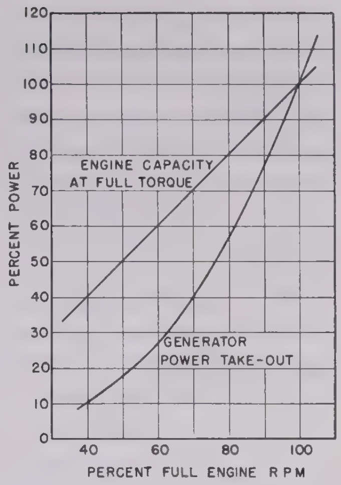
In the case of a d-c trolley-electric locomotive, which uses motors similar in type to those of a self-propelled electric locomotive, the voltage of the system is relatively constant. To apply low voltage to the motors for starting and then to increase it for accelerating, means that resistance must be inserted in the motor circuits and then cut out in a series of steps until full operating voltage is impressed across the motors. Since the power loss in such resistors is a function of the square of the current value, it is usually expedient to connect the motors first in series relation (to reduce the total current fed to the motors and the resultant high resistor loss) and then, when full voltage is impressed across them grouped in this manner, reinsert resistance and change the grouping to a parallel relationship. In this manner, accelerating losses in the resistors are reduced.

With the variable-voltage generator of a self-propelled locomotive, no accelerating resistor losses are involved. Under these circumstances, it is not necessary to connect motors first in series and then in parallel relationship. Nevertheless, several locomotive builders do resort to this practice, since it enables them to effect a slight reduction in generator size. However, by retaining a permanent relationship throughout the locomotive speed range, several important operating advantages are gained, which weigh heavily toward the adoption of this scheme of connections. Among these are

1. Simplification of the control. The operator's attention is not distracted by the necessity for a change of connections at specified speeds or current values.

2. Power application is continuous and smooth. A change in traction motor connections is associated inevitably with a momentary unbalance of tractive force between groups of motors, causing rough handling of a train.

Figure 3. Diesel engine loading at reduced engine speeds



3. The possibility of overloading a generator is reduced. With series to parallel control, it is possible to draw excessive current from a generator with motors connected in parallel when they should have been series-connected.

4. The smooth control of permanent motor connections reduces the tendency of wheels to slip.

In order to procure the maximum tractive force characteristics of a locomotive, it is customary to gear the traction motors with the maximum reduction which will still insure safe motor operation at the maximum permissible locomotive speed. With such gearing, the locomotive speed is usually low at the time that the maximum design voltage is impressed across each motor. In order to increase the locomotive speed, it is customary to weaken the traction motor field strength by tapping or shunting the field windings in one or more steps. With a trolley-electric or third rail-electric locomotive, the amount that the fields may be weakened is governed by the imminent possibility of sudden and violent rises in the voltage of the power supply system, which tends to cause motors to flash. Since such surges are not characteristic of an individual power plant, relatively weaker fields may be employed for self-propelled motive power, thus increasing the range of locomotive speed over which full power may be utilized.

DYNAMIC BRAKING

Dynamic braking is a system of electric braking in which the traction motors of an electric motive power unit, when used as generators, convert the kinetic energy of the unit and its train into electric energy, thereby exerting a retarding force. This system has been used rather extensively with self-propelled electric locomotives as a by-product of electric propulsion and has been found to be very useful for assisting the train brakes in descending long and steep grades at selected speeds. Its application for normal train decelerations when making a stop, however, has not been too popular because of the increased complication of electric circuits.

Dynamic braking is effected by separating the motor armature circuits from the field circuits and controlling the field excitation to adjust the voltage generated by the traction motor armatures to that which is required. In self-propelled electric motive power, the armatures usually are connected to a resistor for conversion of the electric energy into heat energy for dissipation in the surrounding air. The generator of the power plant, being variable in voltage, is an excellent source of power for excitation of the field circuits. Many operating men are unfamiliar with the possible effective range of dynamic braking and expect full braking to be obtained regardless of the locomotive speed. As a matter of fact, such braking is subject to several limitations which allow full braking effect to be exerted over a relatively narrow operating speed range.

One of the prime limitations, of course, arises from the necessity of maintaining the current values through the motor armatures and through their fields within limits which will not overheat the equipment. Another requirement is that the voltage generated by the armatures be held within accepted limits to reduce the possibility of insulation failures. A third consideration is the commutating characteristics of motors at high speeds when large currents are passed through the armatures, while a fourth limitation is the permissible ratio between the armature and the field currents, as established by the machine stability against flashing. All of these, then, delineate the dynamic braking characteristics in terms of speed and tractive force.

Figure 4 shows a typical dynamic braking envelope of a diesel-electric locomotive, wherein a single fixed value of dynamic braking resistance is provided. The curve from *A* to *B* is for continuous rated armature amperes, the shape being determined by the maximum safe generated voltage. From *B* to *C*, the armature amperes must be reduced progressively as the speed rises because of the commutation characteristics at high amperes and high speeds. From *C* to *D*, a greater ratio of armature amperes to field amperes causes instability and possible flashing, while the line from *D* to *O* is the minimum desirable field current for stable control. The curve from *O* to *A* shows the rise in armature amperes with speed for a fixed (maximum) field current.

The dynamic braking characteristics of a locomotive at speeds above that of point *A* are somewhat inflexible, and are fixed by the characteristics of the electric traction motors. However, by reducing the value of the braking resistor, the curve *O-A* may be tipped upward and the braking effect increased at lower locomotive speeds. To reduce this in steps, of course, requires additional control equipment and seldom is found to be expedient for self-propelled motive power.

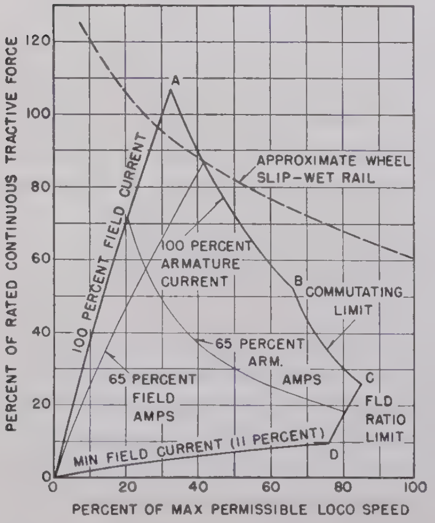


Figure 4. Dynamic braking envelope in which a fixed value of dynamic braking resistance is provided

The efficacy of dynamic braking as compared to the maximum braking which might be applied is indicated by an approximate adhesion (wheel slip) curve drawn to the same co-ordinates. With the fixed value of braking resistance selected for illustration (which is in actual operation at present), full braking effect can be obtained only over 11 per cent of the locomotive speed range, or from 29 per cent to 40 per cent of the maximum permissible speed. Above 40 per cent and below 29 per cent speed, the braking force falls away rapidly from the curve which shows the maximum permissible braking as determined by wheel slippage. However, this envelope gives very satisfactory performance under heavy grade conditions when assisted by the train brakes. Care must be taken, however, to see that the locomotive brakes are not applied when braking dynamically, as the adhesive limit may be exceeded.

Resistance braking has had much wider application on diesel-electric locomotives than on any type of railroad motive power and has made the railroads conscious of this additional advantage of the electric locomotive. When dynamic braking is incorporated in trolley-electric locomotives, a regenerative type normally is applied so that the regenerated power may be returned to the power system, thereby increasing the operating economy. In most instances, this complicates the locomotive control circuits much more than the resistance type of braking used for self-propelled electric locomotives.

VENTILATION

The rotating machinery of electric locomotives must be small, of light weight, and of relatively high capacity. This is especially true of the self-propelled electric locomotive, where the power plant and accessories occupy most of the space available above the locomotive deck, and the predominance of the swivel truck type of running gear limits the space for traction motors. In addition, the cost of self-propelled locomotives is high in relation to the reciprocating steam locomotive, which dictates that all production costs must be kept to the minimum. In the interest of low size, weight, and cost, such large capacity machinery must be force-ventilated to a high degree with cool air.

Very little heat is generated in the equipment compartment of an electric locomotive fed from an external power supply; what little there is can be directed away from the electric motor ventilating systems. The reverse is true of the self-propelled electric locomotive having a power plant, because there is considerable waste heat, and special care must be exercised by both the locomotive builder and the railroad to insure a full supply of cool air at all times.

Accepted practice for self-propelled locomotive generators has been to mount a ventilating fan directly on the armature shaft. Since full load usually coincides with maximum prime mover speed, full ventilation is available when needed. Blowers for traction motors are separate machines, driven electrically at times but more often directly from the prime mover. When driven electrically, full ventilation may be maintained at all times, but with a direct drive (or its electrical equivalent where an engine driven alternator and induction motor fan drives are used) the ventilation fluctuates with the prime mover speed.

As noted, with direct ventilating fan drives, full air volume usually coincides with full equipment heating. However, there are many times when this is not the case. For instance, when pushing freight cars over a hump in order to classify them, full rated tractive force and equipment ventilation may be required, but since the train speed is very low (three to four miles per hour), the horsepower requirements are low. In self-propelled electric locomotives, low horsepower usually is developed at low prime mover speed, under which conditions equipment ventilation is also low. Another case is in dynamic braking. At times when full braking force is being developed and armature heat is generated at the full rate, the generator speed (and consequently the traction motor ventilation) is usually low, since only the power for energizing field circuits is taken from this source. These two cases illustrate the need for thorough consideration of the equipment's ventilation problem in the design and application of self-propelled electric locomotives.

The operating personnel of the railroads are often neglectful of the equipment's ventilating equipment. Fan drive belts may be loose and slipping, air passages may be partially obstructed so that hot air is taken from the engine room instead of from outside, or air connectors to the motors may leak. Any such conditions which tend to increase the temperature of ventilating air or reduce its volume is an invitation to failure in service and increased equipment repair expense.

IMPROVEMENTS OF DETAILS

The tremendous growth in the use of electric motive power within the past 12 years has spurred the development of many details of electric equipment. Roller-type armature bearings are used almost invariably in modern motors and generators, while the felt-wick lubricator has replaced wool waste packing for many types of bearings. Motors and generators for self-propelled electric motive power, not being subject to high-voltage surges or lightning, need not be insulated as heavily as those for trolley-electric locomotives, thus leaving more space for copper. The use of fabricated steel frames, wedged armatures, nonmagnetic bands, and improved copper sections have assisted greatly in increasing equipment capacity without increase in weight and size. Technological improvements of this kind, with a vast background of intense and varied diesel-electric services, are exerting their influence on equipment designs for trolley-electric and third rail-electric motive power.

RENAISSANCE

Electric motive power has changed considerably in character since the advent of the self-propelled types of locomotives. Seldom are the merits of a high center of gravity discussed now in relation to a locomotive design, nor the necessity of a minimum of unsprung motor weight. Flexible drives between a motor and an axle no longer are considered essential for high-speed service. Swivel truck designs are commonplace, where articulated truck construction once was considered imperative for heavy duty locomotives. Where high horsepower per driving axle once was deemed an accomplishment, the desirability of such construction is now very questionable except for locomotives which may be assigned to specific duties.

Almost all modern electric motive power is being built now with low weight and low horsepower per axle, the total required locomotive horsepower being obtained through the use of an increased number of axles. Since it is usually difficult to extend this to an unlimited number of axles under a single motive power unit, the result is generally secured by coupling several smaller units together to form a locomotive. Such construction also improves the utilization of individual motive power units, since one may be easily replaced for inspections or repairs without withdrawing the whole locomotive from service.

The d-c axle-hung motor with a single reduction spur-gear drive has proved to be entirely satisfactory for any type of self-propelled locomotive and for all classes of service. This is a definite simplification over many of the older trolley-electric locomotives. The modern high ventilation rates, resulting in high capacity with a minimum size and weight, are partly responsible for this result.

The release of the electric locomotive from the confines of electrified tracks by the addition of one or more prime movers to each locomotive has disclosed some of its inherent characteristics which could not be fully utilized under previous operating conditions. Also, the remarkable development of the self-propelled electric locomotive has promoted standardization of equipment parts which has never been found practical for trolley-electric locomotives. This has resulted in immense savings to the railroads.

Motive power philosophy has undergone a reversal because of the self-propelled locomotive. Where trolley-electric or third rail-electric locomotives were fitted to specific operating conditions with few locomotives of similar construction, mass production has necessitated a standardization of the former and services are now fitted to the capabilities of these standard sizes of self-propelled units, which has been found entirely practical. The influence of the railroad operating personnel and the mechanical engineer has also been felt strongly. Instead of recommending complicated electric control equipment, they have advocated, in fact forced, adoption of simple circuits and apparatus without loss of reliability. In this respect, self-propelled motive power has advanced a long way.

With the construction of new types of prime movers in progress, still further attributes of electric motive power are expected to emerge, especially as technological advancements occur. One such improvement in prospect, as an example, is the use of high-temperature (class H) insulation, which should reduce the service limitations now imposed by the time-temperature factors of commercial electric equipment application. The electric locomotive, long thought to have reached its zenith, again is leading the way toward improved railroad transportation.

A Square-Law Power-Level Recorder

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THE DEMAND for more accurate measurements of power levels, as well as the increasing interest in the frequency characteristic of voice and carrier channels, filters, high-fidelity amplifiers, and so on, has created the need for an instrument to record these measurements quickly and accurately.

In the square-law power-level recorder, the alternating voltage to be measured is applied to the input terminals of a ladder-type slide-wire attenuator which is adjusted by the balancing motor so that the output voltage of this attenuator is always returned to a standard value. This method, which is the same as the standard manual method of making attenuation measurements, eliminates the need of designing an a-c amplifier having reproducible characteristics over a large range of input voltage, and the need for a dynamic element with a logarithmic response.

In the next step, referring to Figure 1, the attenuator output is amplified by an a-c amplifier and then goes through an inverter stage before being "detected." The detector may be designed to function from its peak input voltage, from its average input voltage (after rectification), or, preferably, from the mean of the square of its instantaneous input voltage. This "square-law" type of detector is preferred because it handles an input composed of two or more components of different frequency in such a way that their relative phase has no effect upon the mean detector output. A full-wave detector employing two pentodes is used. The circuit constants of the tubes are so adjusted that the detector has a square-law response.

In order to obtain the same type of recorder performance for increasing signals as for decreasing signals, the output of the detector is filtered and limited. This direct voltage is reduced by a standard d-c supply and by the direct voltage generated by a tachometer, the remainder being amplified by a d-c amplifier. The tachometer, mounted on the slide-wire motor shaft, generates a voltage proportional to the speed of the recorder and thus prevents overshooting. The output voltage of the d-c amplifier goes to the grids of the double-triode converter. This tube controls the firing of the two thyratrons that control the direction of rotation of the slide-wire motor. When the voltage across the grids of the double-triode has one polarity, one thyratron will fire and the motor will move the slide-wire attenuator towards the balance position. A reversal of polarity causes the second thyratron to fire and the motor to move the attenuator in a reverse direction, but again towards the balance position. In all cases, the motor moves the attenuator so that the input to the a-c amplifier is always brought to the same alternating voltage when the recorder is at the balance position.

The position of the slide-wire attenuator, which is indicated by the pointer of the recorder and recorded by the pen on the chart, is a measure of the power level of the input to the recorder above the zero reference level.

The instrument, has a scale linear in decibels and a range of 40 decibels above a zero reference level of 0.0002 milliwatt with a 125-ohm input impedance. (Recorder ranges of 20, 50, and 60 decibels also have been built.) The frequency error is less than 0.1 decibel between 20 and 200,000 cycles. Abrupt changes of power level of 30 decibels can be recorded in 1.5 seconds. The limit of error is ±1/3 per cent of full scale over its frequency range, provided peaks in the wave form of the voltage being measured do not exceed four times the rms value of that voltage. The performance of the recorder is independent of line-voltage variations or changes in frequency of the line voltage. It requires no batteries, being entirely a-c operated. The record is made on a chart driven at speeds of two inches per minute or four inches per hour.

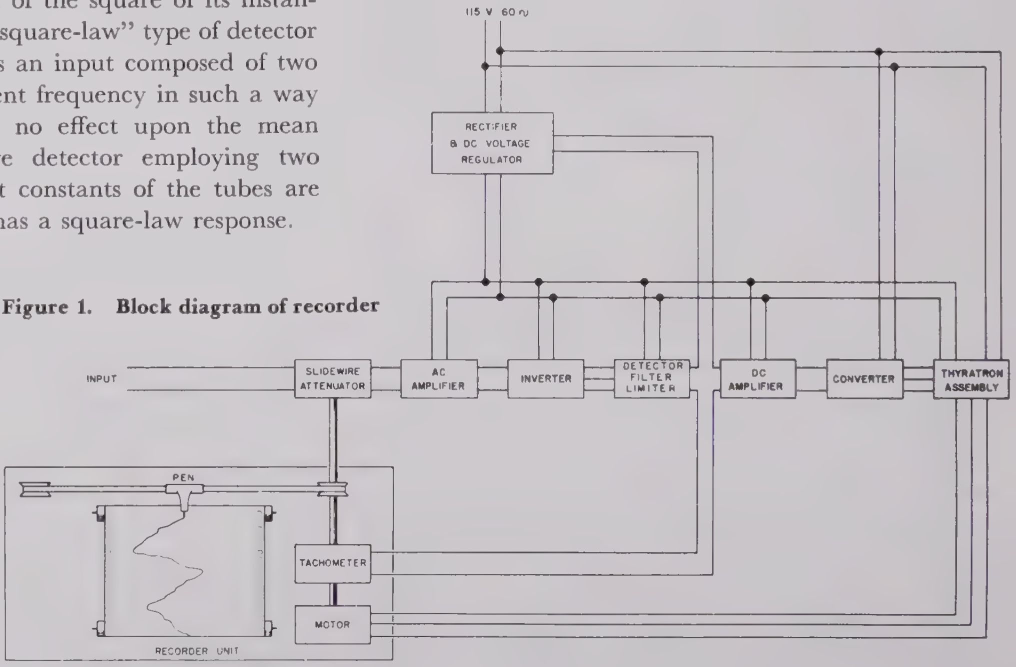

Figure 1. Block diagram of recorder

Digest of paper **49-120**, "A Square-Law Power-Level Recorder," recommended by the AIEE Joint Subcommittee on Electronic Instruments and approved by the AIEE Technical Program Committee for presentation at the AIEE Winter General Meeting, New York, N. Y., January 31–February 4, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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High-Voltage Cable Failure Mechanism

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The mechanism of electrical failures at power frequency is fairly well established and accepted. An analysis of the process helps to correlate the observed performance of cable insulation and to explain the underlying characteristics of the different types. It appears, as discussed in this article, that dielectric failures of any solid or quasi-solid body are of the same general character.

THIS ARTICLE is intended to be a picture of the framework upon which may be hung the practical experience with insulation of high-voltage cables, as well as the basic related theory. It is intended to interpret practical experience concerning dielectric strength in terms of the best available theories. It is hoped that this discussion may serve as liaison between the practicing engineer and the scientist whom he terms "high brow." The practicing engineer is inclined to resent the exposition of theories in abstruse form. He knows that when he himself gets through with his engineering analysis, he must translate it into terms understood by the nontechnical people who often must implement his engineering. By the same token he expects that the findings of scientific research shall be brought out, perhaps not in the language of the streets, but at least into engineering language. It is the purpose herein to accomplish something toward that end.

Just what happens when insulation fails upon being subjected to high voltage at power frequency? (Note particularly that this discussion relates to power frequency and surge voltage, *not to direct current.*) While the basic considerations are believed to apply rather generally to other dielectrics, this article deals, for convenience, with a specific type of dielectric, namely impregnated paper insulation. Failure results (or is initiated) because ionization begins in some part of the dielectric that, in terms of its strength, is more highly stressed than the remainder. In the "solid-type" cable, there are places within the insulation field which are not filled with impregnated paper or with oil, the so-called "voids." In the solid-type cable, it is in one of these voids, usually (though not always) adjacent the conductors, that ionization begins; then, as shall be discussed, failure comes about as a result of the progressive deterioration starting at one of these places of initial ionization.

Accordingly, it becomes important to discuss in some detail just what is the significance of this ionization. There is in any gas space, at any instant, a limited number of free electrons. When insulation is placed under electrical stress, these electrons are attracted toward the positively charged conductor and will travel through the gas, colliding at intervals with molecules and reaching a speed that is a function of the voltage stress and of the mean free path, that is the distance the electrons travel between collisions. With a sufficiently high dielectric stress the speed of the electrons will be great enough so that the collisions will result in the knocking off of additional electrons, that is producing "secondary ionization." This is a rapidly cumulative process and is like the beginning of an avalanche on a mountainside. The electron stream is stopped rather promptly, however, when it reaches the adjacent paper layer, just as an avalanche on a mountainside might be stopped, at its very beginning, by a tree or a boulder. The expressive word "avalanche" has been commonly used to describe cumulative production of electrons by secondary ionization, especially as this approaches or reaches complete disruptive discharge or spark-over. These fast moving particles are identical with what, under other conditions and usually at higher speeds, are called cathode rays.

For our purpose, the fast moving particles may be thought of as producng chemical effects, generally of two kinds. One is the actual breaking down of large molecules into smaller ones, producing finally the charring which is seen on dissection of ionized cable. The other action, which makes large molecules out of smaller ones, is the polymerization of oils, the formation of the so-called wax in cable insulation. The wax formation, so puzzling to the industry for so long, is readily reproduced in other ways by electrical discharges which are, on a larger scale, simply what takes place in the small interstices of the cable insulation. The so-called wax formation is a gradual process involving gradual increase of the oil viscosity, converting a thin liquid into a viscous one and finally into solid material. At the same time gases, mainly hydrogen, are liberated.

The polymerization and wax formation is of relatively small direct importance. However, the polymerized material occupies less volume than before, resulting in an increased total volume of the voids. On the other hand, there is a redistribution of the oil which tends to reduce the size of the larger voids. The net result is often a decrease of ionization with time of voltage application.

The ionization becomes destructive when it is sufficiently severe to produce chemical and mechanical deterioration which finally results in semiconducting paths, and ultimately in tiny holes in a layer of the laminated insulation, as illustrated in Figures 1 and 2. With this process begun, a progressive effect has set in which carries on gradually

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Full text of a paper, "High-Voltage Cable Practice in Relation to Dielectric Theories," presented at the Conference on Electrical Insulation, National Research Council, Washington, D. C., October 27, 1948.

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until failure. The production of a hole through a layer of the insulation increases the length of the path and, therefore, the intensity of the discharge also is increased by its concentration in a smaller area. Thus the action, which was started, continues at an accelerated pace until failure.

This discussion so far has covered the subject in terms of insulation such as solid-type cable containing voids. In oil-filled insulation, even though voids in the sense of gas pockets may not exist initially, it is the conception that an exactly similar phenomenon takes place at a higher stress on account of the ionization of the oil in one or more of the spaces between saturated tapes. Ionization in a liquid is essentially the same phenomenon as in a gas. Because of the shorter distance between collisions—the shorter mean free path of the electrons—a higher stress is required to produce ionization by collision than in the case of gas. Thus in the oil-filled cable the initial ionization occurs within the oil films between the impregnated tapes. This results in disintegration of some of the oil molecules, with the freeing of gas. If the oil previously has been properly degassed as it normally is in oil-filled cable, it will have considerable capacity for dissolving the liberated gas molecules. Finally, after sufficient evolution of gas, bubbles will form within the oil, after which ionization will increase tremendously and failure will follow.

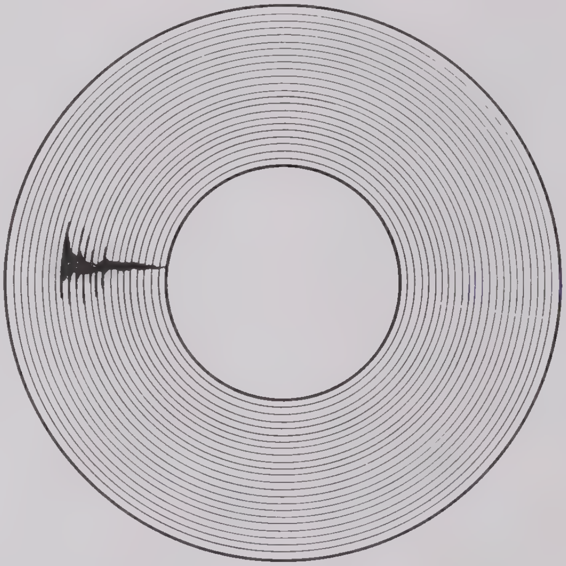

Figure 1. Failure on single-conductor cable, arrested by discontinuance of test

On dissection, tapes with regions of blackened "tracking" are found. These regions are joined by overlying punctured areas of the tapes. As further tapes are removed, the areas of tracking are generally smaller and finally do not occur. The holes in the tapes also become successively smaller. These often may be so small on the inner layers as to be found only with the aid of a (low-power) microscope and then by meticulous care. It is considered that such a failure starts as ionization in a void adjacent the conductor which was sufficiently severe as to produce (or find) a pin-point puncture in the overlying tape. Successive tapes then are punctured gradually and in order. With increasing depth of penetration, a large tangential component of stress is introduced, resulting in tangential discharges which further accelerate the action. With continued application of voltage, this action would continue until failure

The same thought will explain the higher 60-cycle strength which is obtained for high oil pressure cable operating at 15 atmospheres as compared with the ordinary low oil pressure cable of around one atmosphere. In the first place, with the higher pressure, a very much greater amount of gas will be dissolved by the oil before saturation occurs and before the beginning of the rapid failure which will occur when the bubbles begin to form. This is not an adequate explanation, however, of improved long time power-frequency strength. The increase in long time strength, which has been found, seems to be caused by an increasing level at which ionization takes place in oil as the hydrostatic pressure to which it is subjected is increased.

This theory of ionization within a gas film or oil film, gradually leading to failure, brings into a pattern the whole subject of dielectric strength and dielectric failure. Any stress below that at which destructive ionization occurs should produce no deterioration whatsoever and should permit indefinitely long life, as long as there are no changes in the insulation due to causes other than ionization (such, for example, as drainage of oil with resulting increased void space). When the stress is raised above that at which destructive ionization begins, the length of time to produce failure is a function of the severity of the ionization and the resulting rate of propagation of the failure, and thus is a function of the stress. All of this is in line with practical experience and with the voltage-time relationships which have been found on test.

In a graduate thesis published in *AIEE Transactions* in 1910, H. S. Osborne, since then president of the AIEE, outlined a "needle-point" theory which is a very effective forerunner of our present understanding of this type of electrical failure. Robinson of Great Britain, in a book published first in England and then in the United States, has given an excellent detailed analysis of this phenomenon as it occurs in cables. This layer-by-layer failure as a result of ionization forms the basic picture around which all of our understanding of dielectric failure must revolve. If all layers of the insulation are equally strong, ionization will begin in the region of maximum stress and will go on to failure. This statement is not equivalent to support of the maximum stress theory which would determine insulation thickness for a given conductor size and voltage purely upon the stress at the conductor surface. That theory requires the further assumption of equality of specific strength of the insulation of cables of different dimensions. This assumption is not warranted because, with moderate-sized conductors, a better quality of insulation can be produced than with very large conductors. This disadvantage of the large conductor is largely a function of the bending of the cable, both in fabrication and in handling after manufacture. The smaller the conductor with respect to the outside diameter, the less will be the distortion of the inner layers as a result of conventional amount of bending.

Various other factors, as well, have some significance including the facts that, with the large conductor, a greater proportion of the insulation is at substantially the maximum stress and that the greater surface of insulation on the large conductor produces a greater area in which failure may take place on a given length of cable. This last factor is one of the most obvious differences unfavorable to a large conductor but is actually insignificant in amount.

Finally, it is more difficult to use grading effectively with a large conductor than with a smaller one. This difference may be illustrated where grading is accomplished by the use of thinner tapes near the conductor. Other things being equal, insulation made with thin tape has higher dielectric strength than that made with thicker tape because the thickness of the voids decreases along with the thickness of the tape. However, mechanical problems increase with reduction of tape thickness. This is partly on account of the lower mechanical strength of the thin tape, but more particularly because the stiffer thick tapes are better adapted to withstand, without creasing and buckling, the sliding which must occur during the bending of the cable. These mechanical problems are less on the inner layers than on the outer ones, and particularly so where the conductor is small. Accordingly, with the smaller conductor, much more effective use can be made of the better dielectric strength obtainable with thin tape.

As a result of these and other causes, cables of different conductor sizes will not ordinarily fail at the same maximum stress even though, in a given cable, it is generally the maximum stress which determines the strength of the cable. Whatever the cause, in practice, the strength of cables with large conductors is much lower in comparison with those having smaller conductors than would be expected from a simple direct application of the maximum stress theory.

The relationship of the geometry of the cable to the maximum stress has been known and discussed for 45 years. But no adequate basis has been accepted as to the practical significance of the mathematics. Some 25 years ago, at least three different persons (Peaslee, Hoover, and Atkinson) proposed, in somewhat different language, a theory that, as the over-all voltage on a cable is increased, "overstressed" portions of the dielectric might continue to support stress, but in a decreasing proportion to the total voltage and without damage until the insulation as a whole becomes overstressed. These theories have been recently quoted with favor. Actual measurements fail to support them. It has taken a long period of partial understanding to reach what seems today a very simple and adequate understanding of the mechanism of failure, and the relationship to failure of the simple geometry of the cable.

It can be stated that it is usually a space within the region of maximum stress in which failure begins, and thus constitutes the limitation of dielectric strength. However, failure may be initiated in a region not at the maximum stress if the character of the insulation in that region is such that destructive ionization begins at a lower over-all applied voltage than required to produce that effect in the maximum stress region. Whitehead has shown several examples of this condition.[1]

The relation between dielectric strength and the specific gravity of the paper used is the subject of apparent anomaly. In the cable models which Whitehead studied, the insulation, which was wound on a rigid mandrel, was found to be of a greater dielectric strength with the paper having the lowest specific gravity, which showed that this relation is because of the lower stress in the oil spaces with the low density paper as a result of its lower dielectric constant. These findings do not accord with the practice in cable insulation. There, all of the paper used is of higher density than that which Whitehead found to give the maximum strength; in many cases the density is very much higher than this, actually in the range of that which produced for Whitehead the lowest strength. Why should there be this difference? The explanation is that, in commercial cables which are subject to bending as contrasted with Whitehead's rigid mandrels, it has been impossible, with the soft low density paper, to develop the full strength of the insulation. In short, with the soft paper there would be enough cases where the paper of one layer lying over the butt spaces of the previous layer would be damaged mechanically and therefore electrically, so that the effective size of the void is two or three times as great as if the paper were not damaged. Improved manufacturing control has reduced the amount by which the low density papers are inferior as a cable insulation but practical experience still indicates an advantage for the higher density paper. With such paper, strengths have been obtained on actual cables as great as obtainable on Whitehead's cable models.

Not infrequently, dielectric strength has been estimated as a summation of the strengths of the individual layers. A more common form of embodying this idea is the discussion of the "lining up of weak spots." That is, it often has been thought that if two or more noncontiguous weak areas exist in any cross section, the insulation is weakened more than would have occurred by any one of them. With respect at least to power frequencies, this thought is wholly inconsistent with the theory outlined and advocated herein. If a failure, having once started in an overstressed area continues until complete failure, any additional electrically weak spots will have no bearing on the failure. It is true that the minor reduction which it will produce on the time to cause failure can be translated into a lower electrical strength, but this is of an insignificant amount. So long as there is such overwhelming evidence that failure results in this progressive manner, any practical evidence seeming to support the theory of the effect of lining up of electrically weak spots must be ascribed to mechanical weakness; such, for instance, as undue mechanical stress on, and rupture or partial rupture of, tapes in such a way as to increase the effective depth of some of the voids.

Essentially, if any layer of insulation has sufficient dielectric strength as not to be the source of initial failure, the only electrical effect it may have upon the dielectric strength of the cable is the effect which it has upon the stress in the remaining part of the insulation. Thus, aside from dielectric loss, the only electrical effect of any layer other than the one which initiates the failure is related to its dielectric constant.

In the case of surge voltage, there are fairly few experimental data to establish the initial cause and progress of failure. It is rather generally accepted, however, that failure begins in the portion of the dielectric that is proportionately weakest and progresses from there to final failure. In short, likewise, the failure for such voltage application is a function of the maximum stress, again qualified by the same reference to homogeneity and equivalency of insulating values. There has been some speculation as to whether surge voltage application may injure insulation and weaken it against further tests, without an actual failure. Some data have been obtained showing that there is no material injury if the voltage does not approach, too closely, the surge breakdown strength. However, successive tests at voltages closely approximating (within five or ten per cent) the final failure voltage have shown that a definite and serious injury may take place without the puncture being carried through to final failure.

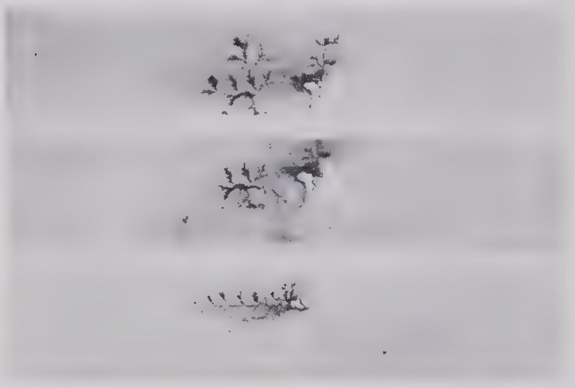

Figure 2. Paper tapes charred in dendritic pattern by electrical discharge

These markings, called variously tree-design or dendrites, are shown in the blackened region of Figure 1 in edgewise projection. They are formed, in the process of development of failure, wherever there exists a sufficient tangential component of the electric field. As a "needle-point" failure gradually extends out from the conductor into the insulation, discharges begin probing laterally on the inner faces of successive tapes, the charred tracks serving as a visual record of the location and intensity of the discharges

Solid-type cable, as already discussed, makes an excellent example by which to illustrate failure as propagated from a small overstressed area progressively to adjacent areas and finally to complete rupture. This is because the strength of the cable is so much lower after the voids have been formed by heat cycles than on similar unheated cable which thus has relatively only very small voids. This difference makes a very striking practical illustration of the effect of these voids on the strength of insulation.

All of the more modern types of paper-insulated cable use one of two means to overcome this source of weakness in the strength of the insulation. The oil-filled types, whether low-pressure or high-pressure, utilize a reservoir into which the oil is forced during periods of increasing temperature and from which the oil is forced back into the insulation in times of decreasing temperatures. In both the low- and the high-pressure type, the oil is returned under sufficient pressure so that there shall be no voids in the sense in which these occur in solid-type cable. That is, the entire volume under electrical stress is occupied at all times either by oil or paper. The same result is accomplished in compression cable by changing the shape of the cross section of the cable. These different types of oil-filled cable (including the compression type) simply use different mechanical means to accomplish the single electrical result. All evidence points to the fact that the effect on the insulation of any electrical stress that is insufficient to produce ionization within the oil will produce no alteration whatsoever on the insulation and no effect other than the liberation of heat caused by whatever dielectric losses may be present.

The other method of avoiding the destructive ionization that occurs in the region not occupied by the paper tapes in solid-type cable is to supply to the entire mass of insulation a positive gas pressure with an inert gas, usually nitrogen. Contrary to the practice in solid-type cables, these "gas pressure" cables are purposely not completely impregnated when the manufacture is complete. Initial impregnation may be completed in a manner similar to that for solid-type cables but the impregnating fluid is removed from the cable while at an elevated temperature; shrinkage of the saturant during cooling, with or without some additional drainage of the hot oil, leaves a space which is filled with nitrogen under pressure prior to operation. Alternately, the cable may be made with preimpregnated tapes in such a manner as to accomplish the same purpose. Gas-pressure cables are classified into three general classes depending upon the amount of pressure.

In low-pressure cables, the gas pressure is of the order of one atmosphere (gauge pressure). Medium gas-pressure cables, of which comparatively few have been installed, use pressures of the order of three atmospheres whereas the high-gas-pressure cables use a pressure of the order of 15 atmospheres. In each case, the advantage of the pressure is the resultant increased stress at which ionization in the gas begins. The low gas pressure can be supported by the lead sheath with no special provisions. The medium gas pressure has been used with a reinforced sheath. For the high gas pressure, metallic pipe is used, or in some cases, a somewhat elaborate reinforcement of the lead sheath.

In all of these cables no electrical effect results from any electrical stress which does not produce ionization. Moreover, although any ionization produces some change, the changes produced by a limited amount of ionization are not necessarily destructive. Indeed, in low-gas-pressure cables, the continued operation at a stress producing limited ionization may result in changes which materially reduce or nearly eliminate ionization at that stress.

The type of failure which has been discussed is inherently different from that caused by cumulative heating resulting from dielectric loss which properly may be called pyroelectric. Dielectric loss failure takes place when more heat enters the cable than is carried away. An inherent characteristic of this type of failure is that improvement of cooling conditions is just as effective in preventing failure as is reduction of applied voltage. Conversely, if the improvement of cooling conditions would not result in ability to withstand a higher voltage without failure, then the failure is not a dielectric loss failure.

Another characteristic distinguishing dielectric loss failure from the ionization type discussed in the foregoing is that the dielectric loss failure is "reversible" whereas the other is not. That is, insulation subjected to the first stages of dielectric loss failure will recover completely if allowed to cool providing it has not been subjected to temperatures which would have injured the insulation had there been no electrical stress. On the other hand, any changes produced by ionization are permanent and irreversible.

From one standpoint, even the ionization failures might be arbitrarily described as pyroelectric. High particle velocity is a characteristic of high temperature and temperature is defined in terms of mean particle velocity. However, to classify all failures as pyroelectric is without merit. It is difficult to see any constructive value, with reference to stresses at power frequency, in the pyroelectric theory promulgated a number of years ago by K. W. Wagner and which received a considerable acceptance. The very valid distinction existing between the cumulative heating type and the ionization type of failure permits each to be studied separately and allows clear-cut practical engineering development to be made separately.

The essential basis of this discussion is applicable to nearly all insulation problems. The solid dielectric materials have inherent or potential dielectric strength which is tremendously large in terms of the stresses at which it is practical to use them. This practical limitation is because all these materials contain in the mass of insulation, incipient faults, large or submicroscopic. When ionized under sufficient electrical stress, generally small compared with the strength of the material if it were entirely homogeneous, these regions are progressively enlarged to the point of final failure. The behavior as described herein is, thus, quite different than what would be expected from applying electrical stress to a solid dielectric structure which is homogeneous down to molecular dimensions.

The effect on the over-all electrical strength by the mechanism described here is somewhat analogous to the reduction in strength of a glass rod or plate which is scratched or notched. Electrical insulation is thus inherently "electrically brittle" in the sense that stress beyond the failure value in a limited region is propagated to ultimate failure of the entire wall. Since the weakness of these regions is a function of their thickness in the direction of the electrical field, laminated insulation such as that made by winding of paper tapes owes its high practical value to the fact that the laminated construction tends to limit the transverse dimensions of these flaws to a distance comparable with the thickness of the individual layers of tape.

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Discussion

High-voltage cable insulation is a very heterogeneous dielectric; alternate layers of oil and paper with paper tapes varying in thickness. These factors when combined with the geometry of the cable and the thermal effects of variable load cycles make the mechanism of dielectric breakdown very complex. To bring out various views by experts in this field the AIEE Insulated Conductor Committee has arranged the following discussions.

G. B. Shanklin (General Electric Company, Schenectady, N. Y.): Anyone who has spent a lifetime in the high-voltage cable engineering field must agree in general, and in most details, with Mr. Atkinson's practical approach in explaining the mechanism of breakdown.

A very interesting paper appeared recently, "An Introduction to the Mechanism of Dielectric Breakdown and Insulation Failure," by Dr. D. T. Hurd, *General Electric Review*, December 1948. Dr. Hurd deals with breakdown in gases, liquids, and homogeneous solids from the standpoint of a theoretical physicist. A study of these theories is a necessary approach to Mr. Atkinson's empirical method of dealing with breakdown in composite insulation, such as represented by high-voltage cable. Mr. Atkinson concludes that breakdown in cable insulation is always instigated at some weak spot, which is usually a gas void or pocket. In the absence of such voids, he concludes that the next weakest spot where failure is instigated is an oil film. Mechanical irregularities in the construction of the composite insulation, and other such factors, circumvent the "maximum stress theory" and cause failure to start wherever the weakest spot may happen to be.

Mr. Atkinson admits that his theory is a bit oversimplified, but no one who has studied failure behavior in insulated cable can deny his practical observations and conclusions. Undoubtedly, the pure theories of molecular breakdown expounded by Dr. Hurd are superimposed.

Mr. Atkinson's approach becomes more convincing the longer the time of voltage application before failure. For very short time voltage applications I am not sure that the ionization type of failure applies. This is particularly true of impulse breakdowns, which Mr. Atkinson deals with but briefly and readily admits that we still have a good deal to learn about. Here also the "maximum stress theory" does not apply any better than it does for longer periods of voltage application, and this indicates that failure is again instigated at weak spots, wherever they may be in the composite insulation cross section. From the limited data available, however, the failures do not appear to be related very closely to void formation and ionization. I always have believed that the mechanism of breakdown under impulse voltage is better explained by an instantaneous physical rupture of the molecules of solid material, instigated at a weak spot and propagated by chain reaction through the whole insulation thickness.

W. A. Del Mar (Phelps Dodge Copper Products Corporation, Yonkers, N. Y.): I am glad to note that Mr. Atkinson, in his excellent summary of present-day theories of dielectric failure pays only formal homage to the maximum stress theory and then proceeds to say that the actual behavior of cables does not match with that theory.

He dissociates himself from the idea that insulation thickness should be based on stress at the conductor surface and finds that, in spite of the maximum stress theory, cables with large conductors break down at lower maximum stresses than cables with small conductors.

However, he explains these anomalies by lack of uniformity of cables and thinks that if the maximum stress theory does not work, it ought to, if given a fair chance.

Peaslee and Hoover developed a theory based on K. W. Wagner's experimental "characteristic curves" of insulation, which show leakage current density plotted against potential gradient. For each value of current density, there is a corresponding potential gradient. Therefore, in a cylindrical cable, as there is a different current density in each layer of insulation, there is a certain potential gradient or stress for each layer. This holds up to a certain current density at which the insulation becomes unstable and the current tends to run away. The inner layers are unable to carry their share of the voltage so that the stress actually falls off at those layers and the maximum stress is no longer at the conductor surface but at some depth in the insulation, and this stress is far higher than the highest attained at the conductor surface. Hoover shows that due to these conditions, design may be made more accurately on the basis of average stress than on the basis of maximum stress as derived from the ordinary logarithmic formula.

How does this check with practice? The Association of Edison Illuminating Companies specifications for both solid-type and oil-filled cables use uniform insulation thicknesses over a wide range of conductor sizes, and the thicknesses are related to the voltages by a nearly linear function in no degree following the maximum stress theory. The designers of low- and medium-pressure gas-filled cables use average stresses, not maxima, to determine insulation thickness.

Mr. Atkinson dismisses the theory of Peaslee and Hoover, which he once espoused and even, to a certain extent, anticipated, on the basis that "actual measurements fail to support this theory." I understand that the actual measurements referred to are measurements of dielectric constant. According to the theory in question, he thinks that the dielectric constant should rise as a preliminary to failure. Undoubtedly this should occur where failure is imminent, but this does not take place along the entire cable under test but only at a weak spot. Failure will occur before the entire cable shows a rise of dielectric constant. Tests of dielectric constant average this quantity over the whole length of cable under test and do not pick out a local rise. Therefore, it is not correct to say that the Peaslee–Hoover theory is not supported by the facts.

Because Wagner's curves were obtained with direct current, Mr. Atkinson assumes that they represent a purely d-c phenomenon, but I see no justification for this assumption and, indeed, would expect the phenomenon to be more pronounced with alternating current.

Indeed, it is with alternating currents that we find those isolated dendrites deep in the insulation, where the Peaslee–Hoover maximum stress should be

I once asked Michael Pupin if he believed a certain theory and his answer was: "I don't believe in theories; I use them." It seems to me that the Peaslee–Hoover theory is a useful one and does not have to be repaired and caulked at the seams to keep it from sinking, like the maximum stress theory.

Probably Peaslee and Hoover conceived of their dielectric as something more uniform than is attained in practice, and thought of the phenomena they were studying as mass effects rather than as local actions.

My idea is that when a certain stress is reached in a dielectric, volume effects cease and the dielectric becomes, in spots, a seething mass of vibrating tapes, flowing oil, vibrating molecules, and electron emission, so that the term "maximum stress" has little meaning, if considered as a mass phenomenon.

It is at some spot weaker than others that the runaway occurs, creating a maximum stress deep in the insulation. The runaway condition at the conductor surface either may start things deep in the insulation or it may create a point discharge as envisaged by Osborne and Robinson. It even may start with Peaslee–Hoover deterioration deep in the insulation and end with Osborne–Robinson "corings."

Thus after going all around Robin Hood's barn, we find ourselves where we started, except that whereas Mr. Atkinson seems to think we know the whole story, I trust that I have shown that a beautiful vista of research is open to an inquiring mind.

Robert J. Wiseman (The Okonite Company Passaic, N. J.): I have read with great interest Mr. Atkinson's paper which he gave before the Conference on Electrical Insulation of the National Research Council, on what is found when high-voltage cables fail either in test or in operation and in the manner that these failures are related to dielectric theories.

Many of Mr. Atkinson's views I can agree with; on others I am not so sure that I can go along with him. It is true that over the past 35 years we have had many theories advanced to explain that which is taking place when a dielectric breaks down when a voltage is applied to it. They seem to conflict, yet in all there is a semblance, in that ionization of the dielectric has to take place before failure occurs. I always have had respect for Dr. Osborne's needlepoint theory, in that breakdown does start at a single point and at the point of maximum stress when we have a homogeneous dielectric. This is fundamental in the ionization theory of breakdown. I never have been able to go along entirely with Dr. Wagner's views on breakdown being entirely of a thermal nature. This is true when the dielectric is stressed for a long time with the accompanying dielectric losses and the building up of ions in the insulation to the extent that the material becomes conducting.

I am inclined to believe that in our endeavoring to explain the causes of dielectric breakdown and examination of the failure later we are liable to forget the manner in which the test was made. I refer to the time that the voltage was applied, either a constantly rising voltage or one held for a period of time at successive steps or at one voltage above the asymptotic voltage until failure occurs. In the case of the constantly rising voltage, we have, as I view it, a much closer approach to the fundamental conditions to establish a theory of breakdown than for the other two conditions of test. These latter definitely involve heating either because of dielectric loss over a long period of time which is a thermal failure or an accumulation of ions which, of course, also produces heat, but is localized, whereas the former is general throughout the dielectric.

It so happens that impregnated paper insulation, which is used for high-voltage cable, has such a high dielectric strength in modern cables that it is not possible continually to raise the voltage on a cable until failure occurs. We test the cable in voltage-time steps and, therefore, at once we are departing from any basis for getting a true indication of dielectric strength. To be sure, we are getting a more practical viewpoint as to what the dielectric can withstand when electric stress is applied and, therefore, can establish a basis for design, but we should not condemn the maximum stress theory of a dielectric because of it. Any statements along these lines should be well qualified.

I would suggest that close attention be given to Mr. Atkinson's views on what happens in an impregnated paper cable when it fails. It could be elaborated upon, but it would take considerable space to do so.

Mr. Atkinson discusses the development of ions in the gas in the voids by means of impact of the electrons of free ions, as I like to call them, with molecules. We call this ionization by impact and it exists in all dielectrics subject to electric stress where the stress is high enough to give the necessary speed to the electrons and the mean free path is such that the electron hits a molecule and more ions are formed to continue the action. Finally a condition is reached where the number of ions are great enough to cause the dielectric to become conducting. These ions accumulate at the region of highest stress, at the conductor in the case of a cable. The effective thickness of insulation as a dielectric is reduced and finally failure occurs because the dielectric strength of the insulation has been reached.

On a short time test, say a continuously rising voltage, the chance of an accumulation of ions by ionization by impact is much less than on a long time such as a constant voltage test. Consequently, it will take a higher voltage or stress to obtain breakdown, but we more closely approach the true dielectric strength of the dielectric.

Why does a low-pressure oil-filled cable require a higher voltage to breakdown for the same wall thickness as compared to a solid cable? I attribute it to two reasons: firstly, as Mr. Atkinson points out, we do not have any gas spaces or voids and the amount of gas in the oil or paper is extremely low because of the high degree of evacuation we apply to this type of cable; secondly, there are much fewer free ions in oil and in paper than exist in gases and the mean free path is higher and more difficult to penetrate. This means we must apply a higher electric stress to produce the ions necessary to produce conduction. Here also the time the voltage is applied will determine the dielectric strength.

Why does pressure cause an increase in the voltage necessary to produce breakdown? Two reasons: if there is gas present, it is compressed to a smaller volume and we have the influence of thin wall dielectric strength and also the electron barrier action in the oil and paper increases, preventing movement of ions.

This viewpoint of dielectric breakdown is based on the Townsend theory of ionization by impact and which I elaborated upon in my thesis at Massachusetts Institute of Technology in 1915, entitled: "The Dielectric Strength of Cables." I showed at that time that if the law of voltage breakdown for a single conductor cable was modified from the theoretical form $V=Kr\ln R/r$ to one expressed as a corona law, namely,

$$V=K_0(1+a/\sqrt{r})r\ln R/r$$

where V=voltage at breakdown, r=radius of conductor, R=radius of insulation, K=stress at the surface of the conductor, K_0=dielectric strength of the dielectric, and a=constant.

This law states that the actual stress to cause breakdown is a function of the conductor size. For the same ratio R/r a small conductor will take a higher voltage to break down the insulation than a large conductor. My studies were made on Ozokorite, a noncrystalline wax, and tests were made with samples having constant and varying values of R/r for different thicknesses. Although the number of tests were not too great, they were sufficient to get curves for study purposes.

In 1922 there were some interesting papers presented before the AIEE ("Insulating Materials," by F. Fernie, "On the Minimum Stress Theory of Cable Breakdowns," by D. M. Simmons, "Potential Gradient in Cables," by W. I. Middleton, C. L. Dawes, and E. W. Davis) in which maximum, average, and minimum stress theories were discussed. As a result I studied the data which resulted in my paper presented before AIEE in 1923, entitled, "The Apparent Dielectric Strength of Cables," which showed the corona law was more applicable with the addition of the term $\sqrt{R}$ into the formula so as to read

$$V=K_0(1+a/\sqrt{r})r\sqrt{R}\ln R/r$$

We have replaced K by $K_0\ (1+a/\sqrt{r})\sqrt{R}$, that is, in the theoretical formula, we say

$$K=K_0(1+a/\sqrt{r})\sqrt{R}$$

If $K/\sqrt{R}$ as ordinates is plotted against $1/\sqrt{r}$, a straight line will result. Where the line crosses the ordinate axis, is the value of K_0. A perfect dielectric would show a line parallel to the horizontal axis, which means the dielectric strength is independent of conductor size. As departure from a pure dielectric occurs, the line will show an inclination. It may slope either upward or downward towards the ordinate axis. If sloping upward the formula will take the form $K=K_0\ (a/\sqrt{r}-1)\sqrt{R}$. If sloping downward, the formula takes the form $K=K_0(1+a/\sqrt{r})\sqrt{R}$.

The manner in which the line slopes can be determined only by tests over a range of conductor sizes and insulation thicknesses. Unfortunately, we have not been able to obtain these curves for impregnated paper cables because of the wide variation in the quality of the insulation for solid-type cables and for the few tests made on oil-filled cables, and all have been step voltage tests. I do feel, however, that the foregoing views can explain in general that which takes place.

I believe that Dr. Whitehead's researches on the influence of paper density (and therefore capacitance) is not strictly applicable to solid-type cables because of the reasons which Mr. Atkinson has stated for the failure of this type cable. I believe they are applicable to low-pressure oil-filled cables if we were to make cables with all one kind of paper over the range in density he used. We have made cables with all one kind of paper (medium dense) and also with super dense paper next to the conductor for grading purposes and we have not noted much difference in the voltage to breakdown. It may have been partially due to the step method of testing, also large conductors and not too heavy walls and moderate grading.

I believe failure on a surge voltage is a maximum stress condition and as Mr. Atkinson states "again qualified by the same reference to homogeneity and equivalency of insulating values."

E. W. Greenfield (Anaconda Wire and Cable Company, Hastings-On-Hudson, N. Y.): During recent years we have heard much from the theoretical physicists and chemists concerning the "design" of molecular structures to produce a substance having stated desirable characteristics. The situation with regard to impregnated paper cable insulation is basically different. A purely theoretical approach does not seem possible at present. Impregnated paper is an exceedingly complex dielectric and if we add to this basic complexity, nitrogenous gas-filled voids, barrier diaphragms of various kinds, shaped conductors and envelopes, graded insulations, vertical and horizontal sections, and heat cycles, the situation from the physicist's point of view is not improved.

I mention these to stress a point which too often is overlooked. Namely, that dielectric breakdown, with which Mr. Atkinson's paper is chiefly concerned, of a given material is almost entirely determined by the conditions under which it must work. Inherent dielectric strength is, in general, poorly related to working dielectric strength, and a worthwhile study of cable breakdown requires knowledge of the condition of every part of the cable insulation structure to the minutest detail. Such detailed knowledge is still unavailable, I believe. When research techniques and improved measuring tools provide such information, the physicist and engineer will team up to provide an adequate theoretical analysis of cable breakdown.

I agree with Atkinson that gaseous ionization is probably the greatest initiator of insulation failure in impregnated paper cables. I do not believe, however, that the "avalanche" type of discharge is a necessary factor. Low-energy continuous bombardment of unprotected paper also can cause permanent damage which will lead to failure eventually. Mr. Atkinson has not stressed the role of temperature in ionization failures. In a gas-filled cable where gas pressure is maintained relatively constant the ionization is found to be greatly enhanced with increase of temperature. This is due to the greater mobility of the ions derived from this increased thermal energy. So too, in a service-aged solid-type cable where the voids have grown sizably large, the ionization increases rapidly as the cable is loaded.

That ionization occurs in liquid dielectrics has been confirmed by us and by many other workers. Under normal temperatures and stresses (below 85 degrees centigrade and 100 volts per mil) the ion mobilities in a much-used type of oil-filled-cable oil are computed to be still too low in energy to cause secondary ionization. Consequently, breakdown from this cause alone is rarely found. On the other hand, when the oil fills the gap between tape-turns near the conductor of a cable, a concentration of ions may occur either chemically produced (copper soaps) or swept in from the paper surfaces, which, under the action of the high gradient, gasifies the oil in a tiny, localized area. The bubble thus formed grows in size under increasingly violent ionic bombardment and unless suppressed by increased oil pressure will fill the entire gap very quickly, thus initiating the insulation damage.

With regard to that ceaseless controversy concerning maximum stress and failure, it is my feeling that every one understands clearly by now how these must be related. Failure, or rather initiation of failure, must be determined by the relation of the maximum stress at a given point in the dielectric to the minimum dielectric strength of the insulation at that point. In any given case, stress is a scalor quantity—a given gradient is just as effective near the conductor as near the grounded sheath or, for that matter, in a plane at right angles to the cable cross section. The ratio of minimum stress at any point to the maximum stress at that point under the conditions of operation is the controlling factor in cable stability. Let us look at this algebraically

$$\text{Strength factor}=\frac{\text{dielectric strength}}{\text{maximum stress}}$$

If the strength factor is greater than unity at every point of the cable, all is well. The difference between its actual minimum value and unity represents the safety factor. On the other hand, if the strength factor is unity or less at any point of the insulation under any of the cable operating conditions, the cable will be damaged in service and fail in a short time.

Use of the term "strength factor" as defined in the foregoing, thus provides a convenient expression for evaluating the electric strength of a cable. It eliminates the somewhat pointless arguments concerning "maximum stress breakdown theory" and "minimum stress breakdown theory." For example in a belted cable, the ratio of the transverse breakdown strength of a certain filler area to the tangential stress in that area may give a strength factor lower than at any other location in the cable. If this value is unity or less, the cable failure will initiate at that point.

It is to be noted, however, that application of the stress factor requires a detailed knowledge of the conditions at every point in the insulation. Failing this, we must calculate the conditions as we know them for the given cable system and apply appropriate safety factors to cover those we do not know.

J. C. Balsbaugh (Massachusetts Institute of Technology, Cambridge, Mass.): Mr. Atkinson has given a very thorough discussion of dielectric principles and practices as related to high-voltage oil-impregnated paper-insulated cables. I should like to restrict my comments to additional fields of experimental study which should be useful in a further interpretation of practical results. It generally is assumed that the paper tapes of the conventional paper cable are thoroughly impregnated. This is probably true from a qualitative point of view. The effect of adsorbed gas within the fiber structure and the known characteristics of the fiber structure itself make ideal or complete impregnation very difficult to attain. It is, furthermore, accepted practice to make accelerated life tests using relatively high voltages in

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relation to the nominal voltage rating. These results are then extrapolated by various means to obtain the life characteristics at normal voltage. I believe that considerable additional information could be obtained by using either higher frequencies or pulse methods at voltages more nearly in line with the actual stresses within operating cable. By this method the severity of the test would be obtained by increase in frequency of the applied voltage instead of by increasing the voltage stress itself. The capacitance of experimental cable sections lends itself quite readily to such experimental studies.

Andrew Gemant (The Detroit Edison Company, Detroit, Mich.): This is an interesting thought-provoking article; the reader can sense that the author writes with authority and knowledge derived from long experience. However, the following few comments have occurred to me in reviewing the article.

The higher strength of a cable operated at 15 instead of one atmosphere is very likely due to an increase of the free energy required for a gas bubble to be liberated, and to an increase of the stress required to produce ionization in existing voids. The ionization process in the liquid phase itself is probably unaffected by such relatively low pressures.

I agree with the author in his view regarding the maximum stress theory. In order to avoid misunderstanding in the mind of the reader, it might be useful to emphasize strongly that the maximum stress principle as applied to cables is fundamentally correct; it is merely modified in a secondary manner by differences in the intrinsic strength for cables of different sizes, as explained in the paper.

The question of the lining up of weak spots touches a difficult problem. Several noncontiguous, overstressed voids lying close together reduce the strength of the insulation more than one void alone, I believe. The Townsend current initiated in one of the voids spreads by means of a capacitive current through the insulation to the next void, where the current is further magnified, and so on. Several noncontiguous voids thus might act as one long gaseous path, producing ionization currents larger than would one void only.

The critical reference to K. W. Wagner's thermoelectric breakdown theory probably is based on a misunderstanding. Except perhaps in his first paper on this subject, Wagner has not maintained that his thermoelectric mechanism is the basis of all breakdowns; he fully recognizes ionization as the alternative mechanism. His and Atkinson's points of view are identical on this matter.

Denis M. Robinson (High Voltage Engineering Corporation, Cambridge, Mass.): Mr. Atkinson's paper was of great interest to me because of its extension to the case of ionization in oil, the phenomena of which I studied some years earlier and described in my book, as well as in the *Journal*, The Institution of Electrical Engineers, volume 77, 1935, page 90.

Mr. Atkinson suggests that cable wax is produced by the polymerization of the oil. The chemists use this word to indicate the joining together of hydrocarbon molecules without any change in the relative proportion of the hydrogen and carbon. Cable wax is probably richer in carbon and poorer in hydrogen than the oil from which it is formed. This process, the binding together of the carbon chains, combined with a freeing of some of the hydrogen previously in combination, is known by the chemists as "condensation." I stress this because the hydrogen so released is undoubtedly a factor in furthering gaseous breakdown, and the condensation process taken to the limit results in the formation of the element carbon without any hydrogen attached. The carbon, being conducting, increases the local stress enormously.

Mr. Atkinson's suggestion that the avalanche ionization occurs in the oil itself in the case of the more completely oil-filled cables is an interesting one. I think it is most unlikely, however, that this point has yet been reached in practical cables, even when greatly overstressed. The mean-free path in a liquid insulation is orders of magnitude less than that in a high-pressure gas pocket, and the inception of avalanche ionization in the liquid would correspondingly be at a voltage much greater than that now used. I think it much more likely that there occurs in the oil-filled cable the same phenomenon which I was able to reproduce under the low-power microscope in glass-walled test samples. The high stress applied to the cable causes ionization in some small—perhaps even microscopic—gas bubble within the dielectric. If the stress is not too great, this ionization actually helps the oil to dissolve the gas, the gas bubble disappears, and the ionization "heals." If the ionization is strong enough, the gas bubble grows instead of diminishing because further gas is evolved, and the trouble spreads, eventually causing tree-like patterns on the paper, of which Mr. Atkinson shows some excellent samples.

If this explanation is accepted, the increase in long-time strength with pressure mentioned by Mr. Atkinson is related to the correspondingly increasing gas pressure in the gas bubbles.

I agree fully with the author's statement that no deterioration whatsoever is produced at a stress below that at which destructive ionization occurs, and that above this stress the length of time to failure is a function of the stress. I also can confirm his statement that carbonization takes place in voids away from the conductor, in the case of belted cable, where the tangential stress is high and the voids large.

J. B. Whitehead (Johns Hopkins University, Baltimore, Md.): The fact that breakdown in good cable insulation usually begins in a very minute point long has been recognized. A pre-existent gas layer or bubble may ionize to spark or corona, and attack or burn the adjacent paper, thus increasing local stress; a small conducting path or entrapped bubble within the mass of the paper may heat or ionize sufficiently to attack the adjacent layers of oil or paper; oil in the channels between tapes may break down disruptively.

Mr. Atkinson proposes that all of these, and perhaps other types of local failure, are due to "avalanche" failure of the oil. It seems to me unnecessary to limit the type of initial ionization in this way. A very low intensity layer of gaseous ionization may initiate an ultimate failure, and has none of the features of an avalanche. The word "avalanche" commonly has been used to describe complete disruptive discharges, such as in sphere-gaps or lightning strokes.

In connection with failure beginning in the oil channel, I quote from the Whitehead–Kopper paper, "The Dielectric Strength and Life of Impregnated-Paper Insulation," AIEE *Transactions*, volume 64, 1945, page 171.

> Under increasing stress the first disturbance of the original condition is the liberation of small gas bubbles in the oil channels. This occurs when the crest value of the a-c stress wave reaches the breakdown stress of the oil. The computed value of the stress in the oil channels at final failure of the specimen in the paper density studies is from 1,000 to 1,500 volts per mil. The maximum disruptive strength of the purest hydrocarbon liquids is about 3,000 volts per mil, that of a good cable oil substantially lower. The difference between these figures and those above is to be found in the free ion content of the oil after impregnation, and more important, in the consequent increase in stress near the paper surface by the accumulation of space charges in each half cycle.

R. W. Atkinson (General Cable Corporation, Bayonne, N. J.): I feel that the discussions warrant the belief that the theory I have outlined of the processes leading to dielectric failure is a fairly accurate exposition of the idea rather generally accepted by those who have given extensive thought to the subject. The discussions, generally, expand upon and amplify the theme or are on somewhat parallel lines and generally help to build up this theme or bring out additional ideas not inconsistent with it.

Del Mar, alone, takes general and rather sharp issue with the main theme. He argues for the "Peaslee–Hoover" theory. Many pages of the 1922 *Transactions* (which contains Peaslee's suggestion) are devoted to speculations and discussions concerning the mechanism of dielectric breakdown. Included in these pages, are several suggestions that "overstressed" insulation may continue to carry stress without damage. Most of these authors were thinking, as was Peaslee, of the stress distribution as being controlled by the conductance of the insulation. For direct current the theory has considerable logic and plausibility as well as some backing of experimental data and I shall not be surprised if it should be further substantiated in the future. For direct current the effectiveness of the theory calls for changes in conductivity that are only trifling—for instance of the same magnitude as the changes produced by only a very few degrees change in temperature. But Peaslee appears to have intended, specifically that his remarks concerning the stress distribution for direct current would apply also to alternating current. He apparently did not recognize that, with alternating current, the stress distribution is controlled by the capacitance and that conductance would play no serious part in this distribution unless it were increased around a hundred-fold or more.

Del Mar proposes that the change of distribution is by capacitance changes. He speculates that a "weak spot" shows up not as a local incipient failure, but as a local increase of dielectric constant. The speculation further predicates that successive adjacent layers do the same thing and that, finally, some layer fails and that the failure then is propagated in a manner not dissimilar to what I have described. Thus, he accepts the final mechanism of gradual, step-by-step, or layer-by-layer, propagation of the failure. But he urges us to accept what seems a gratuitous intermediate stage, a significant stress relief for the inner layers for which I have not seen supporting data.

I am puzzled that Del Mar should be so emphatic now in considering that maximum stress "has little meaning . . .," whereas in 1948 he presented a paper in which all of the data on dielectric strength were given in terms of maximum stress and there was even no reference to average stress.[1]

We owe something to Del Mar for his quotation of Pupin's "I do not believe in theories—I use them." That quotation deserves much repetition.

Gemant has made an important contribution in pointing out that the views of K. W. Wagner concerning the ionization mechanism of breakdown, expressed in writings later than the one to which I referred, are identical with those I have expressed.

Some confusion has resulted from my likening of the first incipient ionization by collison to an avalanche. Initially this incipient discharge is stopped after a travel of only the thickness of a tape, by the tape against which it impinges. It is the cumulative damage due to these relatively minor occurrences which gradually breaks down successive tapes and results in the major avalanche of complete failure. In any attempt to explain dielectric performance it seems most important to emphasize these initial stages which tend to be obscured by the later developments of the failure.

Greenfield points out that secondary ionization does not occur at 100 volts per mil "in a much used type of oil-filled cable oil." Quite true, but electrical failures do not occur in such cables until stresses in the oil reach many times 100 volts per mil. Nor do I know of any reason to expect bubbles to be formed at that stress by a combination of electrical stresses and chemical action which he describes. Greenfield's other comments are with a different emphasis than the writer's but seem not inconsistent with them.

Wiseman expresses a "corona law" for breakdown in which a term is introduced containing the square root of the conductor radius in a manner similar to the law for corona initiation in air. There is a sound theoretical basis for the use of this term, but, since, before failure has set in, the free path of the ions is normally limited to the thickness of a tape, the magnitude directly explainable by it must be very small. However, in view of the fact that the practical results are in the direction predicted, this explanation of Dr. Wiseman's must be considered pertinent. He introduces a further term including the outer radius of the insulated conductor. This term scarcely can have a sound theoretical basis since one of his formulas which includes it gives infinity as the dielectric strength of insulation between flat plates. Thus, while the term might be used to express in mathematical form some observed data, it cannot help to explain the observations.

For the reasons stated by Robinson, it would be better usage, in all instances, to say "condensation" instead of "polymerization" to describe the process of wax formation in cables. Robinson suggests that even in a cable saturated in degassed oil (which avidly will dissolve gas bubbles) there still may be residual minute gas bubbles, and that ionization starts in these. While this thought is not easily accepted, it should not be discarded, especially since it makes a very helpful explanation of the dependence of the strength of such a cable upon the pressure. Very pertinent to this subject is the experiment of H. H. Race in which he produced visible corona in an oil bath, which continued for a time and then resulted in puncture, presumably when the oil became gas-saturated.

Here is a parting speculation. Can it be that when the highest stresses are reached in oil-filled paper insulation, the ions which begin the action are electrons drawn from the metal electrode by the electrical field? Can the freedom of extraction of these electrons from the metal be affected sufficiently by the hydrostatic pressure in the oil to explain the effect the hydrostatic pressure has upon the 60-cycle strength? This may be a useful seed for thought.

The discussions not mentioned herein contribute materially to the picture but call for no comment here.

REFERENCE

1. Characteristics and Development of New York–Long Island Polyethylene-Sheathed Compression Cable, **W. A. Del Mar, E. J. Merrell.** AIEE *Transactions*, volume 67, 1948, pages 452–6.

Electrical Essays

Faraday's Law of Induction II

A 2-Sided Surface Bounded by 2-Turn Coil

"If S is any smooth, continuous surface bounded by a single, smooth, continuous closed curve, then always the integral of the electric intensity, E, around this closed bounding curve, $\int E_s ds$, is equal to the negative rate of change of the integral over the surface, of the normal component of the magnetic flux density, B.

$$\int E_s ds = -\frac{\partial}{\partial t}\int\int B_n dS$$

"True or false?

"Author's answer: False."

The preceding is an electrical essay which appeared in *Electrical Engineering*, June 1948 (*p 530*).

In his answer the author gave as an example, the Moebius strip illustrated in Figure 1, and observed that such a strip is one-sided and that therefore Faraday's law cannot apply to it, since Faraday's law implies some criterion for determining a positive direction to the normal at any point of the surface, and this cannot be given for a one-sided surface.

The "single, smooth, continuous closed curve" which bounds the Moebius strip is shown in Figure 2 and is nothing more than the curve followed by the conductor of a plain ordinary 2-turn coil! Surely, Faraday's law applies to such a coil.

It then must be possible to construct a 2-sided "smooth, continuous surface," which is bounded by the "smooth, continuous closed curve" followed by the conductor of the 2-turn coil. Given such a surface, we may take, over it, the integral of the normal component of B and thus determine the flux linkages Φ of the coil, to which the equation $E = -\frac{\partial\Phi}{\partial t}$ may be applied. Without such a surface, no meaning can be attached to the idea of flux linkages of the coil.

Question! What does such a 2-sided smooth, continuous surface look like?

J. SLEPIAN (F '27)

(Associate director, Westinghouse Research Laboratories, East Pittsburgh, Pa.)

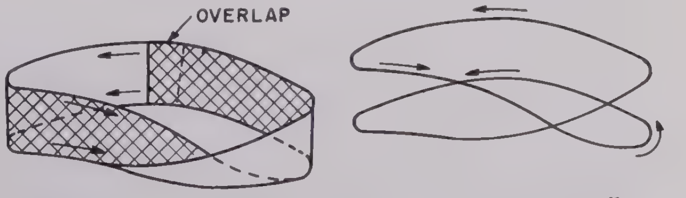

Figure 1 (left). Moebius strip bounded by 2-turn coil
Figure 2 (right). Two-turn coil

The Steinmetz Network

A young distribution engineer is diligently studying a piece of apparatus recently purchased by his employer for supplying power to a series street light circuit from primary distribution lines. The equipment involved is essentially made up of two reactors and two capacitors connected as shown in Figure 1. The ohmic impedance of each of four elements at 60 cycles is equal to x. The network often is referred to as the Steinmetz network. The network relates the rms voltages and currents as follows:

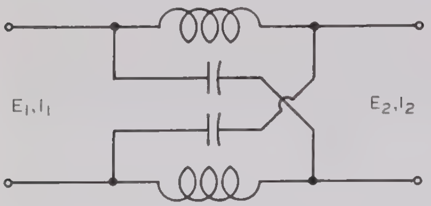

Figure 1

$$E_1 = xI_2 \qquad (1)$$
$$E_2 = xI_1 \qquad (2)$$

(*Note:* The currents and voltages at each end of the network are not related by the network itself but depend on the external circuit constants.)

One of the engineer's coworkers suggests that time and effort can be saved if the young man only would apply Thevenin's theorem to the problem. The young engineer reads a page in a textbook and proceeds with his calculations. Assuming an applied primary voltage and the secondary terminals of the network open-circuited he calculates the open circuit voltage to be infinity. Also, with the primary voltage made zero, the impedance of the network when measured at the secondary terminals is found by him to be infinite. On the basis of these calculations the Steinmetz network must be represented by an infinitely large voltage and an infinitely large series impedance.

Is this correct?

A. A. KRONEBERG (F '48)
(Southern California Edison Company, Los Angeles, Calif.)

Answers to Previous Essays

A Nonlinear Problem. The following is the author's answer to a previously published essay of the foregoing title (*EE, Jun '49, p 518*).

The magnetic flux, ϕ_1, threading the primary winding is periodic. The counter electromotive force developed by the flux ϕ_1 is

$$e_c = -k\frac{d\phi_1}{dt} \qquad (1)$$

where k is a constant factor depending on the system of units used. The counter electromotive force is almost equal to the impressed voltage. Thus for a sinusoidal applied voltage

$$e_1 = E_1 \sin \omega t = -k\frac{d\phi_1}{dt} \qquad (2)$$

which does not define the flux but only its derivative.

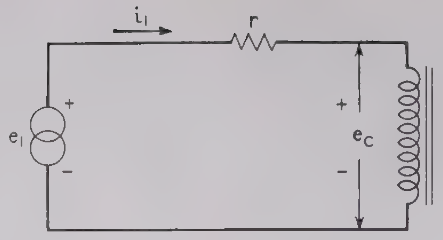

Figure 1

Solving equation 2,

$$\phi_1 = \frac{E_1}{k\omega}\cos \omega t + \phi_0 \qquad (3)$$

where ϕ_0 is the average value of the flux and is yet to be determined.

The flux is determined by the net magnetomotive force on the core:

$$\phi = Ai_1 + Bi_2 \qquad (4)$$

where A and B are dimensional constants.

The secondary current i_2 has an average value different from zero and, therefore, it follows that if the average value of the flux, ϕ_0, is zero that the primary current, i_1, must have a nonvanishing average value. If i_1 has a zero average then ϕ_0 must exist.

Consider the primary circuit, Figure 1, with the insertion of a very small resistance, r. e_1 has zero average value. Therefore, if i_1 has an average value there must be an average value of the volt drop across r. This can be only if e_c has an average value.

$$\mathbf{e}_c = -k\frac{d\phi_1}{dt}$$

and average $\mathbf{e}_c = \frac{1}{T}\int_0^T e_c dt = -\frac{k}{T}\int_0^T \frac{d\phi_1}{dt}dt$

$$= -\frac{k}{T}\int_{\phi_1 \text{ at } t=0}^{\phi_1 \text{ at } t=T} d\phi_1$$

ϕ_1 is periodic. Therefore ϕ_1 at $t=0$ has exactly the same value as ϕ_1 at $t=T$. Thus e has zero average value. It follows that i_1 also has a zero average value and that the flux has an average value.

The development so far agrees with the experiment when the measurement of the average value of the primary current was attempted.

If all this is true, the power line must be delivering power, p_1, to the primary of the transformer during the time interval t_2 to t_3 that no power is delivered by the secondary to the load resistor (Figure 2). The only place this energy can go is into the magnetic field of the transformer.

The power delivered to the magnetic field (neglecting exciting power) is, therefore, the difference between the power delivered to the primary and the power delivered by the secondary to the load.

$$p_1 = e_1 i_1 = E_1 I_1 \left[\sin^2 \omega t - \frac{1}{\pi}\sin \omega t\right]_{t_1}^{t_2}$$

$$= \frac{E_1 I_1}{\pi}\sin \omega t \Big|_{t_2}^{t_3}$$

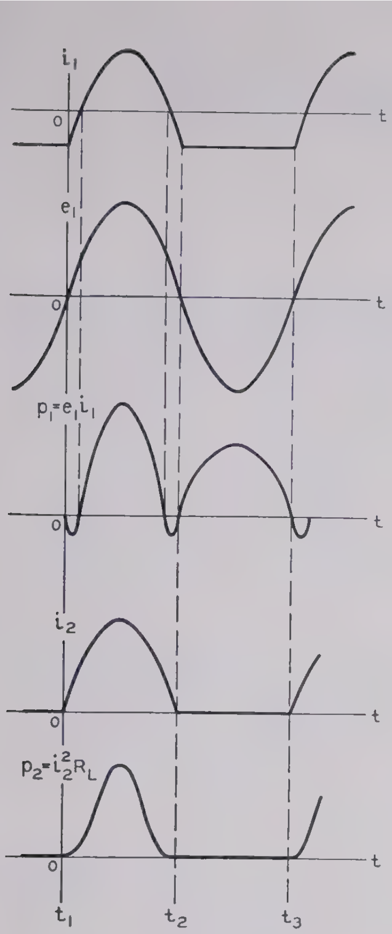

Figure 2

$$p_2=e_2i_2=E_2I_2\sin^2\omega t\Big|_{t_1}^{t_2}=E_1I_1\sin^2\omega t\Big|_{t_1}^{t_2}$$

$$=0\Big|_{t_2}^{t_3}$$

$$p_1-p_2=-\frac{E_1I_1}{\pi}\sin\omega t\Big|_{t_1}^{t_2}\text{(magnetic field energy decreases)}$$

$$p_1-p_2=\frac{E_1I_1}{\pi}\sin\omega t\Big|_{t_2}^{t_3}\text{(magnetic field energy increases)}$$

Thus during the period t_1 to t_2 part of the energy delivered to the load is drawn from that stored in the magnetic field during the period t_2 to t_3 and the required energy balance is obtained.

Although saturation effects were not explicitly considered, the conclusion that the primary current has a zero average value still holds because the average value of the time derivative of any periodic function is zero. These conclusions cannot result if an ideal transformer were considered because the flux in an ideal transformer will increase indefinitely and therefore will not be periodic.

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Which Is the Primary? The following is the author's answer to a previously published electrical essay of the foregoing title (*EE, Jun '49, pp 518–19*).

As the author indicated in his answer to the preceding electrical essay, "Turn Ratio of Transformers," if we do not make use of the saturating or nonlinear properties of the iron core, then it is not possible to determine the turn ratio or primary and secondary leakage reactances of a transformer by purely electrical measurements. Such measurements can give us only the coefficients L_1, L_2, and M of the two equations

$$X_1=\omega(L_1-Mr),\qquad X_2=\omega(L_2-M/r)\tag{1}$$

for the three quantities, X_1, X_2, and r, the primary leakage reactance, the secondary leakage reactance, and the turn ratio respectively. (See author's answer to preceding Electrical Essay, *EE, Jun '49, p 519.*) To determine the three quantities, we need a third equation, or relationship, which can be obtained only in some arbitrary way.

We might agree for example to define an "electrical turn ratio" as given by that ratio of secondary current magnitude to primary current magnitude which for constant primary current will make the mean magnetic energy a minimum. If we take I_1 and I_2 as both real, the magnetic energy will be proportional to $L_1I_1^2+2M_1I_1I_2+L_2I_2^2$; if I_2 makes this a minimum with I_2 constant, then

$$r=|I_2/I_1|=M/L_2$$

This value of r then always will make X_2, the secondary leakage reactance zero.

On the other hand, if we define r as the ratio of secondary current magnitude to primary current magnitude which makes the mean magnetic energy a minimum for constant secondary current, then we get a different value, $r=L_1/M$, and the primary leakage reactance is zero.

Of course both of these possible values of r cannot agree with the actual physical turn ratio. In general, neither will. For the particular case of the toroidal transformer, one of these r's will agree with the actual physical turn ratio, but the engineer will be unable to tell which one.

If we make use of the nonlinear properties of the iron core, then we may define r electrically so as to make it agree very closely with the physical turn ratio for usual power transformers. For example, we may define r as that ratio of secondary sinusoidal current to primary sinusoidal current which for fixed primary current will make the harmonic components of the primary voltage a minimum. For the toroidal transformer, this value of r will be precisely the physical turn ratio, and the engineer of the electrical essay may be well advised to use this idea. For a high reactance transformer such as is sometimes used in arc welding, the agreement of this electrically defined r with the physical turn ratio may be less good.

It is principally because of the saturation properties of the iron core that the analysis of the performance of a transformer in terms of turn ratio and leakage reactances is of value. In the extreme cases where they disagree, the electrical turn ratio defined in the foregoing should be used rather than the physical or geometric turn ratio. If this ratio is used then the nonlinear properties of the core will affect only the "common flux" or mutual reactance of the windings. The leakage reactances, based on the turn ratio so defined, will be nearly independent of current amplitude and free from nonlinear effects.

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Electronic Power-Converter Protection—I

AN AIEE COMMITTEE REPORT

POWER RECTIFIERS of the mercury-pool type must be provided with protection against both overloads and short circuits external to the unit and arc-backs within the unit. Overloads exceeding rated values may occur as the result of unusual conditions in the load circuit, outage of parallel units supplying a common load, or service requirements in excess of installed capacity. In any case, the operation of the rectifier on overload is the same as at rated loads except that the commutating angle increases with increasing load current. This increases the conducting period of the tubes, modifies the anode current and voltage waves, and so changes the duty on the tubes. It also causes the output voltage of the rectifier to drop as the load current is increased.

Short circuits and other faults in the d-c system may reduce the impedance of the load circuit to zero. As the impedance at the d-c terminals of the rectifier approaches zero, the current delivered by the rectifier increases to a limiting value determined by the constants of the rectifier circuit and the output voltage drops to zero. The conduction period of the tubes increases to 180 degrees or more on d-c short circuit. The mode of operation of the rectifier circuit also changes so that the anode current waves are substantially sinusoidal instead of flat-topped.

Faults may occur within the rectifier unit as the result of arc-back in a tube. An arc-back is the failure of the rectifying action which results in the flow of a principal electron stream in the reverse direction due to formation of a cathode spot on an anode.

When an arc-back occurs in a tube, fault current flows from the other transformer phases and their connected anodes to the faulty anode. If the d-c circuit to which the rectifier is connected has other direct voltage sources, the current flow at the positive terminal of the rectifier will reverse and a fault current will flow from the positive terminal through the faulty tube and its transformer winding to the negative terminal.

If there is no feed-back from the d-c circuit and all the reverse current to the faulty anode comes from the other anodes of the rectifier, the fault current is determined by the impedance of the transformer and a-c supply system and by the arc-drop. If there is feed-back from the d-c circuit into the faulty anode, the fault current is determined by the inductance and resistance of the fault path, including the tube arc-drop and the voltage regulation of the current source.

In early rectifier applications, the protective system was quite simple and was based on devices and practices in use on rotating machines. With the growth in size and extent of power-converter installations, the problem has assumed greater importance. Service requirements also have become more severe with larger systems and new applications where continuity of power flow is essential.

The protective system must prevent damage to the rectifier unit and minimize the disturbance to the a-c and d-c systems. Damage may occur as the result of overload and fault currents of excessive magnitude or duration. Such currents either may cause sudden failure of the rectifier, transformer, switchgear, and other parts of the rectifier unit, or may result in rapid deterioration and high maintenance. The reliability and life of the equipment may be affected. The disturbance to the a-c and d-c systems must be limited in magnitude, duration, and extent in order to prevent damage to associated equipment and avoid other operating difficulties.

The protective system comprises both impedance elements for limiting the magnitude of fault currents and interrupting devices for limiting their duration. In order to prevent extension of the fault in the power systems, the fault current must not exceed the ability of associated apparatus to carry fault current without failure, and circuit breakers must provide selective operation.

Information regarding the nature of the circuit action during the fault and the magnitude of the fault current is essential to the design and operation of electronic power converters. Such information is required for the design of the various devices comprising the rectifier unit, the selection of these devices to obtain a properly co-ordinated, economical equipment, the setting of protective relays, and the development of sound operating practice.

Rectifier faults may be resolved into two general types, namely, d-c short circuit, and arc-back. During d-c short circuit, the value of fault current usually is determined in large measure by the circuit reactance, the major part of which generally is located in the rectifier transformer. The circuit action is quite similar to that obtained during short circuits on a-c systems, and the fault currents are of the same order of magnitude. Under arc-back conditions, a more complex circuit action is obtained, with both a-c and d-c systems feeding into the fault. The fault currents may increase manyfold to ultimate values limited largely by circuit resistance.

Equations exist for determining the value of fault current in rectifier circuits under both short-circuit and arc-back conditions in a number of idealized cases. While these equations do not permit the exact calculation of the fault current under all conditions which may be encountered in practice, they do provide means for determining definitive values which are useful in the design and operation of protective systems.

Digest of paper 49-67, "Protection of Electronic Power Converters—Part I," recommended by the AIEE electronic power converters committee and approved by the AIEE technical program committee for presentation at the AIEE winter general meeting, New York, N. Y., January 31–February 4, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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Saving Time in Testing Life

W. R. PURCELL

By using only the median and the shortest life in statistical analysis, the time required to predict performance from a test is accelerated. This article describes how the method was used successfully for saving time in testing life of incandescent lamps; however, this method is just as applicable to many other products.

THE HEART of any technique of controlling quality during manufacture is skillful and scientific trouble shooting. To be scientific, the trouble-shooting procedure should:

1. Leave the process alone when there is no trouble.
2. Apply corrective action when there is trouble.
3. Apply such corrective action promptly while the trouble still exists and before many units of substandard quality have been manufactured.

One of the most useful techniques for determining whether there is trouble to shoot is the Shewhart control chart for measurements. In this technique, limits are set for the average and range of the measurements on periodically drawn samples. As long as the statistics continue to fall within the limits, it is presumed that there is no trouble and that the process should be left alone. As soon as a statistic falls outside the limits, there is strong evidence of trouble and corrective action should be applied. How promptly the corrective action can be applied depends on how quickly the measurements can be made and the statistics computed.

In most applications of this control chart technique, measurements can be made promptly. Thus, the third element of scientific trouble shooting, prompt action, usually can be made a part of the procedure. In certain instances, however, this is not so, and the time required to make the measurements substantially reduces the value of the technique. An outstanding example is the test of life, in which neither the average nor the range can be computed until the last unit of the sample has reached the end of its life.

In many instances, this difficulty has been partially overcome by increasing the severity of the life test. A classic example is the shortening of the life of incandescent lamps from 1,000 hours to about five hours by burning them at 150 per cent of rated voltage. Even at this acceleration, however, it often requires seven or eight hours to burn out the last lamp of a sample; yet the final result might yield an average so small or a range so great that need of corrective action is indicated. Attempts to accelerate the life test further cause abnormal arcs and do not give a true picture of normal life. Since the test cannot be accelerated further, it is necessary to accelerate the statistics.

In conventional statistics, average is used to indicate a shift in the level of the whole population; range is used to indicate a change in population dispersion. A shift in level also can be indicated by the median life, or central failure in the sample; a shift in level or change in dispersion can be indicated by the shortest life, or first failure in the sample. The use of median and shortest as statistics substantially accelerates the results. A tendency toward short life which is indicated by the sample is indicated quickly. It is not necessary to continue the test beyond the median, and corrective action can be started promptly.

Before adopting these new statistics, a preliminary study of the inherent frequency distribution of incandescent lamp life was made. Table I is a typical set of data accumulated before control was established. The data indicate the following conclusions:

1. In the long run the average of the medians coincides with the average of the averages.
2. Both of these statistics are about half way between the average shortest life and average longest life.
3. The differences between median and average in individual samples are not significant. (Average of the range is 410 hours. From this, the standard deviation of units σ' is about 176; standard deviation of averages σ_a about 80. The average of the absolute differences, 40, is only one-half of one standard deviation of averages; the greatest difference, 130 in sample 19, is only 1.62 standard deviations of averages.)

From these conclusions the assumption was made that the inherent frequency distribution of incandescent lamp life is substantially normal.

In control charts, there is a central line about which the statistics are expected to scatter in random fashion just as long as there are no shifts in population center or dispersion. This central line is located at the long-term average of the statistic. Extending this technique to these new statistics, the central line for medians is located at the average median, and the central line for shortest is located at the average shortest.

Conventional limits allow for variations in the statistics which are not significant. These insignificant variations are caused by the constant system of chance causes in the process and operation of chance in sample selection. The control limits are placed at three standard deviations of the statistic above and below the central line of the statistic.

Full text of paper **49-187**, "Saving Time in Testing Life of Incandescent Lamps," recommended by the AIEE Applications of Statistical Methods Subcommittee and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Swampscott, Mass., June 20-24, 1949. Scheduled for publication in *AIEE Transactions*, volume 68, 1949.

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Table I. Typical Data for Life of Incandescent Lamps in Hours Before Establishment of Control

Sample* Number	Shortest	Longest	Range	Median	Average	Difference Between Median and Average
1	270	740	470	580	600	20
2	810	1,140	330	970	1,020	50
3	1,180	1,310	130	1,200	1,260	60
4	860	1,110	250	930	940	10
5	380	1,090	710	1,010	960	50
6	990	1,370	380	1,300	1,260	40
7	850	900	50	850	870	20
8	870	1,740	870	1,300	1,300	0
9	720	1,260	540	1,020	1,110	90
10	740	1,340	600	1,040	1,010	30
11	830	1,140	310	980	1,050	70
12	1,700	2,070	370	1,930	1,840	90
13	680	1,020	340	880	860	20
14	650	1,110	460	970	980	10
15	940	1,070	130	1,020	1,040	20
16	1,160	1,680	520	1,250	1,250	0
17	1,190	1,480	290	1,250	1,340	90
18	1,340	1,490	150	1,420	1,380	40
19	1,180	1,730	550	1,410	1,280	130
20	340	880	540	670	610	60
21	1,100	1,240	140	1,170	1,170	0
22	800	1,550	750	920	970	50
23	930	1,200	270	1,200	1,140	60
24	1,020	1,560	540	1,240	1,210	30
25	690	1,240	550	1,000	980	20
Averages	890	1,300	410	1,100	1,100	40

* Each sample contained five lamps.

A statistic beyond the control limits is then very unlikely if chance is operating alone and, therefore, is considered conclusive evidence that some other dominant cause is affecting the process.

Using this same procedure, control limits for medians are (see Table IV for explanation of notation)

$$UCL_m = \overline{M} + 3\sigma_m \tag{1}$$

$$CL_m = \overline{M} \tag{2}$$

$$LCL_m = \overline{M} - 3\sigma_m \tag{3}$$

and control limits for shortest life are

$$UCL_s = \bar{S} + 3\sigma_s \tag{4}$$

$$CL_s = \bar{S} \tag{5}$$

$$LCL_s = \bar{S} - 3\sigma_s \tag{6}$$

To compute the values of σ_m and σ_s, reference was made to a table of order statistics.[1] This table gives the means and standard deviations of the first, second, third, and so on, statistics of small samples, with reference to the mean and standard deviation of the population.

If attention is confined to the normal distribution, these tables yield, first, a constant K relating the average of the first statistic (shortest life) to the population standard deviation, thus

$$\bar{S} = \overline{M} - K\sigma' \tag{7}$$

Therefore, the population standard deviation is given by

$$\sigma' = (\overline{M} - \bar{S})/K \tag{8}$$

Second, the tables yield another constant C_s relating the standard deviation of the first statistic (shortest life) to the population standard deviation, thus

$$\sigma_s = C_s\sigma' \tag{9}$$

Combining equations 8 and 9

$$\sigma_s = (C_s/K)(\overline{M} - \bar{S}) \tag{10}$$

For odd-size samples, the tables yield another constant C_m relating the standard deviation of the median to the population standard deviation, thus

$$\sigma_m = C_m\sigma' \tag{11}$$

Combining equations 8 and 11, for odd-size samples

$$\sigma_m = (C_m/K)(\overline{M} - \bar{S}) \tag{12}$$

For even-size samples, the tables yield another constant C relating the standard deviation of the (1/2)nth statistic to the population standard deviation, thus

$$\sigma_{(n/2)} = C\sigma' \tag{13}$$

Combining equations 8 and 13

$$\sigma_{(n/2)} = (C/K)(\overline{M} - \bar{S}) \tag{14}$$

In this instance, however, it is preferable, to avoid confusion, to consider the median as the mean of the $n/2$ and $(n/2) + 1$ statistics, thus retaining the same central line. Then, for even-size samples

$$\sigma_m = \sigma_{\{(1/2)\}\{[n/2]+[(n/2)+1]\}} \tag{15}$$

Now, the variance of the sum of two statistics a and b is given by

$$\sigma^2{}_{a+b} = \sigma^2{}_a + \sigma^2{}_b + 2r_{a,b}\sigma_a\sigma_b \tag{16}$$

In our case, our two statistics are the $n/2$ and $(n/2) + 1$ values. Since the distribution is normal, we know by symmetry that these two variances are equal. Therefore

$$\sigma^2{}_{[n/2]+[(n/2)+1]} = 2\sigma^2{}_{(n/2)}[1 + r_{(n/2),(n/2)+1}] \tag{17}$$

Since we want the variance of the mean of $n/2$ and $(n/2) + 1$, and since the variance of a half-statistic is one-quarter of the variance of the whole statistic, then

$$\sigma^2{}_{(1/2)\{[n/2]+[(n/2)+1]\}} = \sigma^2{}_{(n/2)}\{1 + r_{(n/2),[(n/2)+1]}\}/2 \tag{18}$$

or, in terms of standard deviations

$$\sigma_{(1/2)\{[n/2]+[(n/2)+1]\}} = \sigma_{(n/2)}\sqrt{\{1 + r_{[n/2],[(n/2)+1]}\}/2} \tag{19}$$

Combining equations 12, 15, and 19, for even-size samples

$$\sigma_m = (C/K)\sqrt{\{1 + r_{[n/2],[(n/2)+1]}\}/2}\,(\overline{M} - \bar{S}) \tag{20}$$

The values of K, C_s, C_m, C, and $r_{[n/2],[(n/2)+1]}$, which have

Table II. Means, Standard Deviations, and Correlation Coefficients for Certain Order Statistics

n*	K	C_s	C_m	C	$r_{[n/2],[(n/2)+1]}$
3	0.8463	0.7480	0.6698		
4	1.0294	0.7012		0.6004	0.65
5	1.1630	0.6690	0.5356		
6	1.2672	0.6449		0.4962	0.74
7	1.3522	0.6260	0.4587		
8	1.4236	0.6107		0.4326	0.80
9	1.4850	0.5978	0.4075		
10	1.5388	0.5868		0.3886	0.83

* For explanation of notation see Table IV.

Table III. Values for Computation of Median Life and Shortest Life Control Limits

For substitution in: $UCL_m=\bar{M}+T_1(\bar{M}-\bar{S})$; $LCL_m=\bar{M}-T_1(\bar{M}-\bar{S})$; $UCL_s=\bar{S}+T_2(M-\bar{S})$; $LCL_s=\bar{S}-T_2(\bar{M}-\bar{S})$

n	T_1	T_2
3	2.38	2.65
4	1.59	2.04
5	1.38	1.72
6	1.10	1.53
7	1.02	1.39
8	0.87	1.29
9	0.82	1.21
10	0.73	1.14

Table IV. Explanation of Notation

UCL_m = upper control limit for medians
CL_m = central line for medians
LCL_m = lower control limit for medians
UCL_s = upper control limit for shortest
CL_s = central line for shortest
LCL_s = lower control limit for shortest
$\bar{M}$ = average of medians
$\bar{S}$ = average shortest
n = sample size
σ_m = standard deviation of medians
σ_s = standard deviation of shortest
σ' = standard deviation cf population
K = constant relating mean first statistic to population standard deviation
C_s = constant relating σ_s to σ'
C_m = constant relating σ_m to σ' in odd-size samples
$\sigma_{n/2}$ = standard deviation of (1/2)nth statistic
C = constant relating $\sigma_{n/2}$ to σ'
$\sigma_{\{1/2\}\{[n/2]+[(n/2)+1]\}}$ = standard deviation of mean of (1/2)nth and $[(n/2)+1]$st statistics
$r_{[n/2],[(n/2+1]}$ = correlation coefficient between (1/2)nth and $[(n/2)+1]$st statistics
T_1 = constant relating $3\sigma_m$ to $(\bar{M}-\bar{S})$
T_2 = constant relating $3\sigma_s$ to $(\bar{M}-\bar{S})$

been reproduced from the paper cited, are given in Table II.

For simplicity, new constants T_1 and T_2 are established, so that

$$T_1(\bar{M}-\bar{S})=3\sigma_m \tag{21}$$

and

$$T_2(\bar{M}-\bar{S})=3\sigma_s \tag{22}$$

Combining equations 21 and 12, for odd-size samples

$$T_1=3C_m/K \tag{23}$$

and combining equation 21 with equation 20, for even-size samples

$$T_1=(3C/K)\sqrt{\{1+r_{[n/2],[(n/2)+1]}\}/2} \tag{24}$$

Combining equation 22 with equation 10, for any sample size

$$T_2=3C_s/K \tag{25}$$

Values of T_1 and T_2 have been calculated using equations 23, 24, and 25 and the constants in Table II, and are tabulated in Table III for sample sizes from 3 to 10.

The final equations for central lines and control limits are

$$UCL_m=M+T_1(\bar{M}-\bar{S}) \tag{26}$$

$$CL_m=\bar{M} \tag{2}$$

$$LCL_m=\bar{M}-T_1(\bar{M}-\bar{S}) \tag{27}$$

$$UCL_s=\bar{S}+T_2(\bar{M}-\bar{S}) \tag{28}$$

$$CL_s=\bar{S} \tag{5}$$

$$LCL_s=\bar{S}-T_2(\bar{M}-\bar{S}) \tag{29}$$

Example from the data in Table I

$\bar{M}=1,100$
$\bar{S}=\ \ 890$
$n=\ \ \ \ 5$

from Table III, for $n = 5$

$T_1=1.38$
$T_2=1.72$

The control limits and central lines are

$UCL_m=1,100+(1.38)(1,100-890)=1,390$

$CL_m=1,100$

$LCL_m=1,100-(1.38)(1,100-890)=\ \ 810$

$UCL_s=\ \ 890+(1.72)(1,100-890)=1,250$

$CL_s=\ \ 890$

$LCL_s=\ \ 890-(1.72)(1,100-890)=\ \ 530$

Another most interesting application of order statistics in destructive tests has been developed elsewhere.[2]

The statistics of median and shortest have been in use at Sylvania Electric Products Inc., for incandescent lamp life test since 1945.

One advantage in the use of these statistics is the saving in time and facilities required for test. A second advantage is the elimination of the calculation of averages and ranges. There is one disadvantage; for the same sample size, median

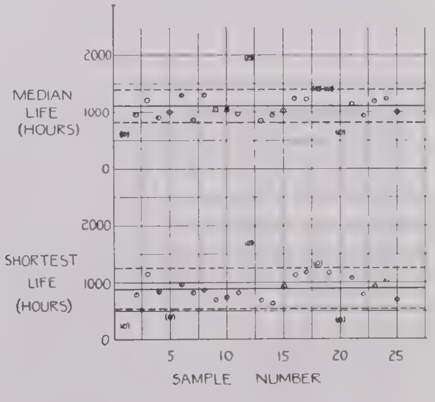

Figure 1. Control chart of data in Table I (control not established)

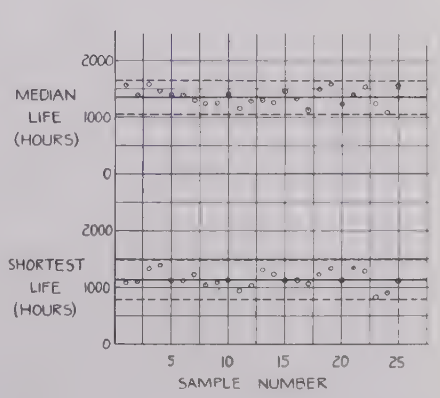

Figure 2. Control chart (control established)

is 10 to 25 per cent less stable and, therefore, as a control statistic is less sensitive than the average.

The great advantage is the speed of the corrective action, which is the very purpose of the whole testing procedure. Furthermore, the fastest action is taken when most needed; that is, when life is short. Figure 1 (control chart of the data in Table I) illustrates this especially for samples 1, 5, and 20. Action on these statistics was possible in the accelerated equivalent of 270, 380, and 340 hours (or slightly over $1^1/_2$ hours). Action on conventional statistics would have been delayed until the accelerated equivalent of 740, 1,090, and 880 hours, respectively, or about $4^1/_2$ hours.

Figure 2 illustrates the appearance of charts based on these statistics after control has been established. The increase in average life and improvement in uniformity have been very gratifying.

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New Uses for Magnetic Fluids

The magnetic fluid originally used in the electromagnetic fluid clutch developed at the National Bureau of Standards has several unique features that make possible other important applications of iron-oil mixtures, according to Technical Report 1346 available from the bureau, United States Department of Commerce, Washington 25, D. C. Further studies of the properties of these mixtures have revealed that magnetic fluids can be employed to good advantage in hydraulic systems, shock absorbers, and dashpots, to form casting molds, and as variable electrical resistors. The basic property on which all these applications depend is that the viscosity of a magnetic fluid is directly related to the strength of the applied magnetic field—the fluid may be changed from a liquid to a nearly solid state and back again at will.

One engineering application proposed in the bureau's preliminary investigation of new uses for magnetic fluids is the magnetic fluid dashpot. Basically, a dashpot consists of a piston moving in a fluid-filled cylinder with the viscosity of the fluid resisting the piston motion. In a conventional dashpot, the rate of travel of the piston is determined by the external force, the fluid pressure on the piston, the dimensions of the fluid escape vent, and the fluid viscosity. The variable usually controlled is the pressure on the piston. The rate of piston travel can be adjusted mechanically by providing a variable orifice in the piston or in the cylinder wall—a method that presents a number of complications.

On the other hand, if a magnetic fluid is used in the dashpot, the rate of motion of the plunger can be controlled readily by magnetically varying the viscosity of the fluid. If a coil of wire is placed around the dashpot, the viscosity of the magnetic fluid will be a function of the current in the coil. Employing this idea in the design of shock absorbers for automobiles and trucks would provide an adjustable riding quality to meet various loading and roadway conditions. The rate of response of the magnetic fluid is high enough to provide virtually instantaneous changes in viscosity, thereby making possible a shock absorber with automatic compensation.

The electromagnetically controllable fluid offers interesting possibilities for use in hydraulic systems. If a hydraulic system is filled with a magnetic fluid, valving becomes extremely simple. By winding a coil of wire around a fluid-carrying pipe and controlling the amount of current through the coil, the flow of fluid past that point can be closely regulated from full flow to complete cut-off. An obvious advantage of this scheme is that various points in a hydraulic system can be remotely controlled from a central station.

Electromagnetic fluids also are being investigated for use in molding operations. A fluid is placed in a pot surrounded by a current-carrying coil, a model of the part to be cast is placed in the fluid, and the coil then is energized so that the fluid will solidify around the model. When the model is removed, a detailed impression remains outlined in the solidified magnetic fluid. Molding compound then can be poured into the mold and allowed to harden. After the coil current is turned off, the molded replica easily can be removed from the liquid. In any application of this kind, the boiling point of the magnetic fluid must be higher, of course, than the temperature of the molten casting material.

An electrical resistor adapted to remote control can be made by immersing two electrodes in a magnetic fluid. When the fluid is in an unmagnetized condition, the resistance between the two electrodes will be extremely high because of the very loose contact among the conductive iron particles that are distributed randomly in the nonconductive oil. In the presence of a magnetic field, however, the iron particles apparently form chains along the lines of magnetic flux and draw into close physical contact. The flux density will determine the massiveness of the chain and, thus, the conductivity of the mixture. When the system is de-energized, the conductance does not drop back to its former very low level. This property of magnetic fluid resistors is attributable to the coherer effect, which has been studied in the past by such well-known investigators as Branley and Marconi.

A description of "The Magnetic Fluid Clutch," by Jacob Rabinow, scientist at the National Bureau of Standards, has been published in AIEE *Transactions,* volume 67, 1948, pages 1308–15, and *Electrical Engineering,* December 1949, page 1167.

Rectifier Fault Currents—II

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A NUMBER of modes of circuit action may be obtained during faults on power rectifiers because of the variety of fault conditions and circuit parameters. Extensive tests have been made on a 6-phase 200-kw 300-volt sealed ignitron rectifier in which calculated and test values of fault currents are in good agreement.

During d-c short circuit, the circuit action is determined by the relative magnitude and location of the various impedances in the rectifier unit and the short-circuit path. Three idealized cases with their equivalent circuits and wave forms are shown in Figure 1. In the first case, all reactance is considered to be located in the rectifier-transformer a-c windings and supply line. The fault currents in the a-c windings are the same as in a 3-phase short circuit on an a-c system. Under transient conditions, the fault-current waves are displaced and the current in the short circuit exceeds its sustained value. In the second case, the inductance and resistance is lumped in the anode leads. Each tube acts independently and the transient current in the short circuit rises gradually to the sustained value. The third case is that with reactance and resistance in both a-c and d-c windings of the rectifier transformer and the circuit action combines the effects obtained in the first two cases.

During arc-back, the circuit action is determined primarily by the sources of voltage producing the fault current. Three idealized cases with their equivalent circuits and wave forms are shown in Figure 2. In the first case, the circuit consists of a 3-phase rectifier and the current flow in the faulty anode is established by the a-c supply. The reverse current in the faulty anode is of pulsating form and is equal to the sum of the forward currents in the two normal anodes. In the second case, the circuit consists of a single path, and all the current in the faulty anode flows in the d-c system. The current consists of an alternating component of constant magnitude and a direct component which increases exponentially with time.

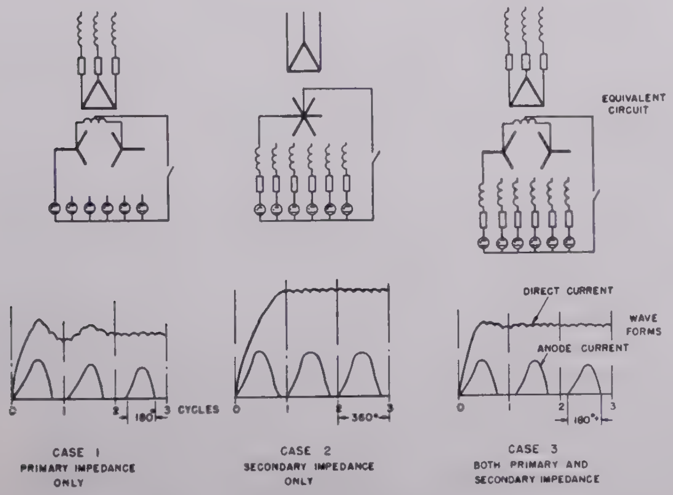

Figure 1. D-c short circuit—idealized conditions

Reactance considered to be located in a-c windings and supply line

The third case in Figure 2 usually is encountered in practice and combines the action of the first two cases. In order to simplify the analysis, the action is considered on the basis of a single Y. During arc-back, the current in the faulty anode is a combination of a-c feed from the two normal anodes of the Y and d-c feed from a single d-c source representing all other anodes and parallel sources. Currents feeding into an arc-back from a counter-electromotive-force load and from the normal anodes in a faulted Y are additive components of the current in the faulted phase. Each of these components is smaller than the value obtained in either case 1 or case 2.

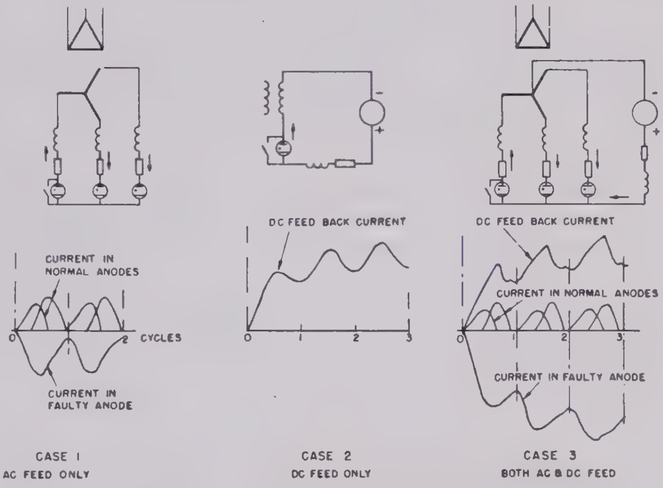

Figure 2. Arc-back—idealized conditions

The reactance of the rectifier transformer and the arc-drop of the rectifier tubes are usually the most important factors in determining the magnitude of the fault current in any particular case. There may be considerable variation in form and magnitude of the arc-drop voltage across a rectifier at fault-current levels. Studies indicate that average values of arc-drop voltage appear to be most representative of the effect of arc-drop on fault currents and that the arc-drop may be treated as a resistance in making calculations.

Digest of paper **49-68**, "Rectifier Fault Currents—II," recommended by the AIEE electronic power converter committee and approved by the AIEE technical program committee for presentation at the AIEE winter general meeting, New York, N. Y., January 31–February 4, 1949. Scheduled for publication in AIEE *Transactions*, volume 68, 1949.

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The Geometric Loci of the Synchronous Tie

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SYNCHRONOUS TIE is the name given to a system of two identical induction machines with stators supplied from a common polyphase line and with rotors interconnected. A rotation impressed on one of the shafts causes a corresponding motion of the second shaft, as if there were a mechanical coupling of some sort. Thus the tie finds uses as a remote indicating or positioning device, and also in applications where considerable power interchanges are required between two distant shafts in continuous synchronized rotation.

For some uses, it is found convenient to modify the rotor circuit to include additional impedance networks. A general study of such a modified synchronous tie is undertaken in this article. The method of analysis is to apply Kirchhoff's laws to an equivalent circuit established with the assumptions used customarily in the circuit analysis of the induction machine.

The operation of the synchronous tie is characterized by two independent variables. One is the common speed of the two shafts, or, if one prefers, the slip s in terms of the speed of the revolving fields; the elements of the branches of the equivalent circuit representing the rotor network therefore are functions of s. The other independent variable is the angular displacement between the two rotors as needed to produce circulating rotor currents and synchronizing torques; the corresponding phase angle δ (in electrical degrees) between induced rotor voltages is simulated in the equivalent circuit by means of an ideal phase shifter inserted in the rotor circuit or at the stator terminals of one machine.

For constant δ and variable s, a family of s-loci is obtained for each of the stator currents, $\boldsymbol{I}_{a1}$ and $\boldsymbol{I}_{b1}$, of the two machines. In parametric form, the expressions are

$$\boldsymbol{I}_{a1}=V\frac{\boldsymbol{A}^{0}+\boldsymbol{A}'s+\boldsymbol{A}''s^{2}+\ldots+\boldsymbol{A}^{\nu}s^{n}}{\boldsymbol{D}^{0}+\boldsymbol{D}'s+\boldsymbol{D}''s^{2}+\ldots+\boldsymbol{D}^{\nu}s^{n}}$$

$$\boldsymbol{I}_{b1}=V\frac{\boldsymbol{B}^{0}+\boldsymbol{B}'s+\boldsymbol{B}''s^{2}+\ldots+\boldsymbol{B}^{\nu}s^{n}}{\boldsymbol{D}^{0}+\boldsymbol{D}'s+\boldsymbol{D}''s^{2}+\ldots+\boldsymbol{D}^{\nu}s^{n}}$$

where V is the line phase voltage and the symbols, $\boldsymbol{A}$, $\boldsymbol{B}$, and $\boldsymbol{D}$, for any given δ represent constant complex quantities. For a simple tie without additional impedances, $n=1$ and the s-loci are circles. For a network consisting of resistors branching in shunt from the straight slip-ring connections, $n=2$, and the s-loci are bicircular quartics. For a tie with shunt capacitors, $n=4$ and the s-loci are curves of the eighth order, and so on.

On the other hand, for constant s and variable δ, a family of loci is obtained in the form $\boldsymbol{I}_{a1}=V(\boldsymbol{H}+\boldsymbol{K}\epsilon^{j\delta})$ and $\boldsymbol{I}_{b1}=V(\boldsymbol{H}+\boldsymbol{K}\epsilon^{-j\delta})$, where $\boldsymbol{H}$ and $\boldsymbol{K}$ for any given s are constant complex quantities. Thus, the δ-loci are circles, whose graphical determination is immediate for any value of s, if the particular s-loci for $\delta=0$ and $\delta=\pi$ are known. These two s-loci (for which $\boldsymbol{I}_{a1}=\boldsymbol{I}_{b1}$) have comparatively simple expressions and can be calculated from design data, or can be obtained directly, within the range of practically interesting velocities, by means of easy tests performed on one single machine of the set.

The general determination of the two stator currents by the method described allows the calculation of powers and torques for any speed and any angular displacement by means of conventional procedures. For each δ-circle it is also possible to draw a torque axis, the distance from the tip of the current vector of either machine to this axis representing the torque of the revolving field in a certain scale.

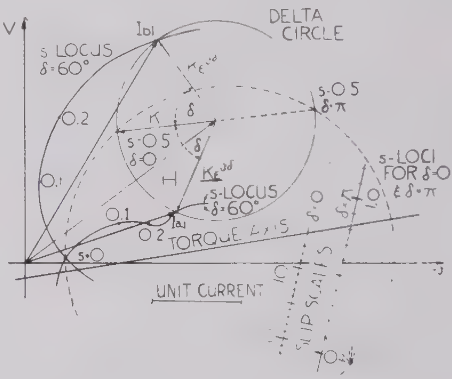

Figure 1. Current loci of a synchronous tie with shunt resistors

Figure 1 indicates the graphical procedures used for the determination of the δ-circle for $s=0.5$ from the two basic s-loci for $\delta=0$ and $\delta=\pi$ in the case of a synchronous tie consisting of two 6-pole 60-cycle 10-horsepower 3-phase motors, with additional shunt rotor resistors which have twice the resistance of the rotor phase winding of one machine. The s-locus for $\delta=\pi$ coincides with the circle diagram of one machine. The s-locus for $\delta=0$ is again the same circle, but it has a different slip scale, as can be seen from the illustration.

Portions of the quartics for $\delta=60$ degrees and variable s are plotted also, as obtained from repeated constructions of δ-circles for various slips, for the sake of general interest only. It may be noticed that both machines of the set develop positive torques at $s=0.5$. In fact, the addition of shunt resistances in the rotor interconnection makes it possible for both machines of the set to operate as motors, delivering mechanical power while keeping in synchronized rotation.

Digest of paper **49-51**, "The Geometric Loci of the Synchronous Tie," recommended by the AIEE rotating machinery committee and approved by the AIEE technical program committee for presentation at the AIEE winter general meeting, New York, N. Y., January 31–February 4, 1949. Scheduled for publication in AIEE *Transactions*.

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Safety Considerations for Electric Blankets

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Electrically heated blankets are judged to be safe from hazards of electric shock and overtemperature if they pass standard tests for current leakage, dielectric strength, and normal and abnormal overheating. Design considerations which affect performance on these tests include the construction of the blanket wired structure, the power rating of the blanket, the type of overtemperature protection used, and the fail-safe characteristics of that protection.

HOW SAFE is an electrically heated blanket? Customers want to know, manufacturers are anxious to learn, sales agencies inquire, and even insurance companies are inquisitive. As this product is an electric appliance, its safe operation usually is judged by safety standards established for electric appliances. Because the many agencies that test blankets have amplified the standard tests, it seems desirable to record the current testing requirements and their effect on blanket design.

ORGANIZATIONS MAKING SAFETY TESTS

The Underwriters' Laboratories, Inc., are perhaps the greatest factor in establishing standards for the safe operation of appliances. They are, however, by no means the only organization which judges the potential hazards of an appliance. Many of the public utilities have independent laboratories, where appliances are tested to standards which may or may not be patterned after the Underwriters' Laboratories requirements. One such standard is, "Fundamental Safety Requirements for Electrical Equipment to Be Used by the Public," which was published in 1933 by the Association of Edison Illuminating Companies. This standard is based on investigations conducted by the Electrical Testing Laboratories acting as technical agent for the appliance committee of the association. Many large department stores have laboratories in which they test electric appliances to determine whether the operation is satisfactory and safe. Some of the requirements that an electrically heated blanket must meet in order to be judged safe and dependable by all of these testing organizations are discussed in the following.

POSSIBLE HAZARDS IN ELECTRIC BLANKETS

There are two types of hazard which can occur in an electrically heated blanket and which are judged critically by all testing groups. One of the hazards is an electric shock, the other is overheating of the blanket; either of these may occur under any condition of operation of the product. In testing the product to evaluate these possible hazards, the test standards of all groups are devised to measure:

1. Hazard protection of the new product under conditions of normal operation.
2. Hazard protection of the product after a period of simulated use.
3. Hazard protection of the used product under abnormal conditions of use.

The standards commonly used to evaluate the absence of electric shock hazard in an electric blanket will be considered first.

ELECTRIC SHOCK HAZARD

In general, a blanket is used in a dry condition, and the insulated blanket wire is enclosed in the textile blanket covering, so there is little danger of the user coming in direct contact with a wire. There is even slighter danger of the user coming in contact with a wire and at the same time touching a ground connection such as a radiator, water pipe, or grounded radio part. It is always possible, however, that a careless user may operate the blanket while it is damp, or that rain may wet the blanket while it is in use near an open window. It is equally possible that a young sleeper may wet the blanket during the night. There is danger, too, that a shock may occur from metal parts of the controller or from damaged insulation on the connecting wires associated with the product.

STANDARD TESTS FOR EVALUATING SHOCK HAZARD

The Underwriters' Laboratories require that the heating wires in a blanket be suitably insulated and of a waterproof type. Compliance with this requirement is measured by immersing a new sample of the wired blanket in a container of water to which sodium chloride has been added in the ratio of one tablespoon per gallon. After the blanket has been immersed for one hour, a potential of 120 volts direct current is applied between the conductors of the blanket wire and the salt water solution. To be acceptable the leakage current must not exceed five milliamperes. As a further measure of any abnormal condition which might create a shock hazard in the new unit, the blanket which has soaked in the salt water solution is tested with a 1,230-volt rms a-c potential between the conductors of the blanket wire and the salt solution. No evidence of voltage breakdown is allowed in this test.

Similar 1,230-volt a-c tests are applied to any exposed metal parts on the controller unit and the controller wiring, and no evidence of voltage breakdown is allowed in this test.

Other testing organizations evaluate the shock hazard

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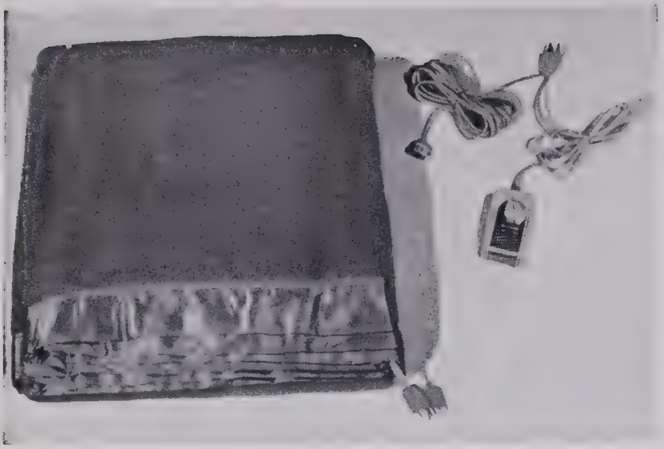


Figure 1. A typical thermostatically controlled blanket showing the thermostatic controller, the blanket containing overtemperature thermostats, and the associated connecting wire

in a new blanket by different standards. In one test the blanket is covered with a layer of tin foil and then is rolled into a tight cylinder. A connection is made to the tin foil sheath and to the conductors in the blanket wire. The prepared unit then is placed in a humidity chamber with a relative humidity of 85 per cent and a temperature of 90 degrees Fahrenheit for 16 hours. The current leakage between the blanket conductors and the tin foil sheath then is measured at a potential of 120 volts rms. To be acceptable, a blanket must have a leakage current of less than 0.2 milliampere.

To measure the possibility of shock hazard in the blanket after a period of simulated use, the complete blanket is flexed for thousands of cycles. The Underwriters' Laboratories flex the blanket by rubbing it over 2-inch pipe rollers under a uniform tension of approximately $1^1/_2$ pounds. The blanket is so flexed for 3,000 cycles on each side, while being energized through its controller unit. This flexing test is intended to simulate years of normal use.

After flexing, the possibility of shock hazard is determined by immersing the blanket in a salt solution and comparing current-leakage and dielectric-strength tests to the Underwriters' standards.

An additional test is applied to the blanket wire to prove its protection even after severe use. Samples of the blanket wire are mounted on swatches of blanket material and flexed over a one-quarter inch diameter fulcrum for thousands of cycles. Present standards require that the energized blanket wire sample remain intact for a minimum of 20,000 flexes (90 degrees each side of the center line) and that the wire sample show no signs of hazard as it is flexed up to 100,000 cycles. After a wire sample has been flexed 100,000 cycles, it is immersed in the salt water solution where current-leakage and dielectric-strength tests are repeated.

PRODUCT DESIGN TO MEET SHOCK HAZARD REQUIREMENTS

To meet such stringent test standards it is obvious that the wiring circuit in the blanket must be well insulated and sealed against moisture. The controller readily may be constructed to meet the shock hazard requirements if standard design practices and electrical clearances are used. The associated wiring (between line, controller, and blanket) usually is made with insulation at least 1/16 of an inch thick to prevent shock hazards that might occur in pinching the cords under bed casters or between bed spring supports.

There are two types of electric blankets commonly sold today. They will be considered separately, because the design problems are quite different.

BLANKETS WITH THERMOSTATS

Thermostatically controlled blankets common today have a thermostatic controller, as shown in Figure 1, which modulates the heat input into the blanket unit according to the ambient room temperature. The blanket unit used with this controller consists of a heating wire, and six to nine overtemperature thermostats assembled into the blanket structure. These thermostats are strategically located in the surface of the blanket and are connected to de-energize the blanket wire in the event of excessive temperature. It is common practice to enclose such thermostats in a sleeve of insulating thermoplastic and to seal this sleeve in a moistureproof fashion to the insulated jacket of the blanket wire with a high-frequency bond. Eighteen such seals within the blanket structure require close supervision and great care in their processing, if the blanket is to meet the afore-described standards of electric shock hazard. These thermostat seals must be designed carefully to remain watertight after the severe flex test.

Of course, it is necessary to use great care in manufacturing and testing the heating wires in blankets to exclude pin holes or imperfections in the extruded insulating jacket. Usually blanket wire is tested by passing it through a 6,000-volt a-c spark tester to indicate any defective spots in the insulation. However, there is no simple equivalent test for proving the perfection of the blanket after the wires and thermostats are assembled.

BLANKETS WITHOUT THERMOSTATS

Blankets of the "electronic control" type consist of a controller unit which functions to control the warmth of the blanket, and which also contains a circuit responsive to excessive temperatures in the blanket unit. The blanket unit used with such a controller consists of a single wire circuit, or two parallel blanket wire circuits terminating in the connecting plug at the foot of the blanket. These uninterrupted lengths of blanket wire are usually spark-tested before assembly to assure that the finished blanket will be completely moistureproof.

EXCESSIVE TEMPERATURE HAZARD

All electric blankets are designed to develop through their controller unit a maximum operating temperature of approximately 100 degrees Fahrenheit on the surface of the blanket heater wire, when the blanket is spread normally on a bed. The electric power necessary to develop this wire temperature varies with ambient temperature, and to be most useful a blanket should have ample power capacity to maintain comfort even in a 30 degree Fahrenheit room. The thermal characteristics of the blanketing material will affect the power requirements greatly. An extremely heavy blanket material will require less electric power to maintain comfortable temperatures in a cold room, but such a blanket also will be uncomfortably warm (even with all power off) in a mildly cool room. A popular compromise of these two factors results in blanket ratings in the range of 200–220 watts as adequate to meet both the cold and the mildly cool requirements.

The Underwriters' Laboratories specify that a blanket shall not be rated in excess of ten watts per square foot of wired area. Typical double blankets have a wired area 54 by 72 inches, hence are limited by the Underwriters specifications to 270 watts.

In normal use a blanket frequently is bunched or folded. Often portions of a blanket are covered temporarily with pillows or clothing. Such folding or covering creates an accumulation of heat in the covered section. To be safe this excessive heat must not cause temperatures which would hurt the user or damage the insulation of the blanket wire, the blanket material, or other bed coverings. When the blanket is operating in a cold room, and the controller is supplying maximum power, the temperatures under the covered portions will be greatest.

The Underwriters' Laboratories require that an electric blanket be so designed that temperatures which will cause discoloration of the fabric will not be developed at any point on or within a blanket which is fully or partially covered and with the controller at the maximum-temperature position.

Regardless of the durability of any particular blanket wire construction, there is always the possibility that the wire may be broken while the blanket is operating. The wire may be broken accidentally, or it may just "wear out." The Underwriters' Laboratories require that the insulation on blanket wire be of suitable noncombustible type and single strand construction, to preclude any fire hazard when the energized wire is broken.

STANDARD TESTS FOR MEASURING TEMPERATURE HAZARD

The Underwriters test the effectiveness of any overtemperature protection in the blanket by covering the flat blanket with a $3^3/_4$ pound (unwired) wool blanket. The blankets are folded to produce eight equal blanket layers (counting both blankets), and a felt pad 14 by 18 inches and one-inch thick is placed over the center of the top blanket layer. Thermocouple temperature measurements are made in the different blanket layers. With the blanket energized at the maximum setting of the controller, no temperature measurement shall exceed 212 degrees Fahrenheit.

Other laboratories make similar overtemperature tests. One laboratory tests the temperatures in the flat blanket when portions of the blanket are covered with a pillow and with a book. They also test the blanket when folded double, and when folded double and covered with an additional blanket.

To determine that the appliance will not overheat after years of use, all laboratories repeat their temperature tests after the blanket has been flexed. In the case of the Underwriters, the flex test has been described. Other laboratories flex test the blanket by folding it double and drawing it back and forth over a 2-inch roller 12,000 times. Flexed blankets are judged to the same maximum-temperature standards as described.

As proof that an appliance meets the safety specifications under abnormal conditions, the Underwriters' Laboratories make the following test. A blanket is laid out in normal fashion on a 6-inch felt mattress. The blanket is energized with its controller set at maximum temperature in an ambient temperature of 40 degrees Fahrenheit. Portions of the blanket are covered with an 18 by 14 inch felt pad one-inch thick. In case the blanket contains overtemperature thermostats the felt pad covering is placed on an area away from the thermostat. Thermocouple temperature measurements are made at various points under the felt pad. The temperature limitations in this test are determined by the scorching temperature of the blanket fabric.

A sample of blanket wire is tested for fire hazard by flexing the energized wire, mounted in blanket swatches in a manner described in the foregoing. Even if the blanket wire breaks, it is allowed to flex for 100,000 cycles to determine that no dangerous sparking or burning will occur. The Underwriters also check the complete blanket for fire hazard by purposely breaking the energized wire and sparking the wire ends in the presence of insulating material, blanket cloth, and blanket lint. No burning is allowed in this test.

PRODUCT DESIGN NECESSARY TO MEET FIRE HAZARD REQUIREMENTS

In the two types of blanket design the problems of overtemperature protection are quite different and will be treated separately.

Blankets With Thermostats. There is seldom any problem involved in designing a blanket thermostat assembly which will limit the temperatures of wholly folded blankets to prescribed values. Usually a compromise is necessary in calibrating such thermostats, however. The lower (and safer) the temperature adjustment of the protective thermostat, the greater the chance that thermostat will inadvertently open if a person casually sits on the bed for a

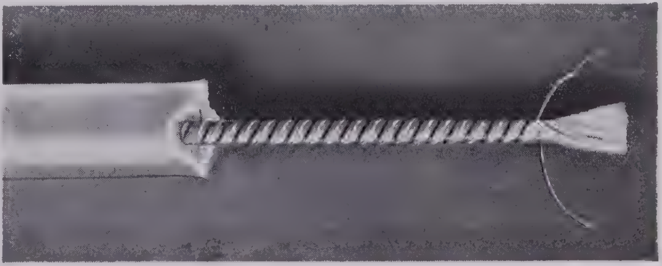


Figure 2. A section of typical blanket wire used in blankets without overtemperature thermostats

The heavy copper conductor (for heating) and the smaller temperature measuring conductor are spiralled about a textile core. Both conductors are encased in an extruded thermoplastic insulating jacket

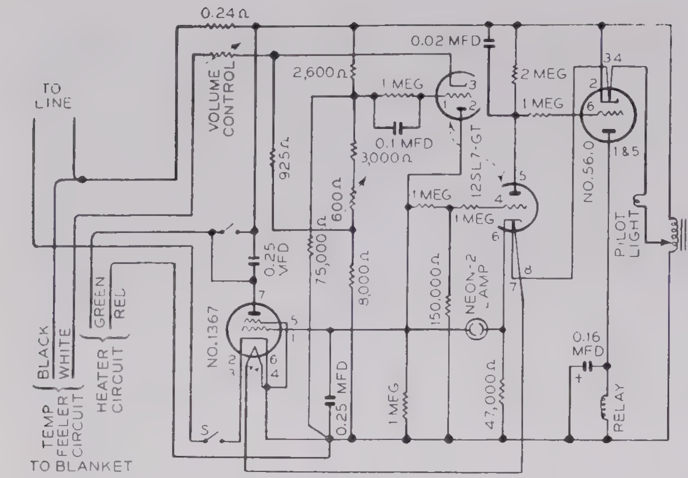


Figure 3. The circuit of a typical electronic blanket controller which maintains the temperature in the blanket at a selected value and does not require overtemperature thermostats

Factory adjustment of 600 ohms: with maximum temperature setting of dial control is just "off" (leads green and red) when 1,360 ohms is connected between leads black and white

moment before retiring. It is difficult for such thermostats to reclose while the circuit is energized, for the heat of the contact arc (on reclosing) is retained in the insulating jacket and makes the thermostat reopen continuously even though the local cause of overheating is removed. In general, protective thermostats are calibrated to open at 140 degrees Fahrenheit, a fair compromise between dependable protection and unnecessary misoperation of the heating circuit.

Obviously the protective thermostats in a blanket must be mechanically strong if they are to maintain their calibration accurately through the severe flex test. Usually the thermostat is enclosed in a metal case within the insulating jacket, so all mechanical strains in flexing are absorbed by the case and not the mechanism. Underwriters' Laboratories test protective thermostats separately under full load for 25,000 cycles, and allow a change in calibration of nine degrees Fahrenheit.

Blankets incorporating thermostats for overtemperature protection are somewhat at a disadvantage in the abnormal overtemperature test, because the felt pad is placed on an area not including a thermostat. As such protected blankets usually are controlled by an external thermostat, this test, when made in a warm room, will result in very low power consumption in any section of the blanket, and the heat loss from the covered section, in general, will limit temperatures to the prescribed value. When this test is made with a blanket in a cold room (40 degrees Fahrenheit), the thermostatic controller will allow near maximum power to be developed in the blanket, and a unit will overheat in the covered section, unless the rated power of the blanket is held in the region of 150–180 watts.

The tests to demonstrate absence of fire hazard when the blanket wire breaks are not severe. Because the blanket swatch is under a tension load of 12 ounces during the flexing test, there is seldom any sparking reaction when the wire breaks. A common blanket wire construction consists of a textile core about which the heating conductor is wound in a tight spiral. This assembly is jacketed in an extruded thermoplastic insulation. When the wire sample is under tension and the conductor breaks, the two ends pull apart instantly and prevent any arcing that might occur. The thermoplastic insulation generally used on blanket wire is a slow-burning type of material which will not ignite in the heat of a spark.

Blankets Without Thermostats. It has been stated that the so-called electronic-control-type blanket provides remotely controlled overtemperature protection in the blanket. Such blankets consist of 2-conductor blanket wire, in which the two individually insulated conductors are spiraled about a textile core and enclosed in an extruded thermoplastic jacket, as shown in Figure 2. One such design utilizes the temperature sensitive leakage resistance between conductors to actuate an overtemperature circuit in the control. Another device has, like the first, a copper heating conductor which supplies heat to the blanket when energized from the 115-volt mains. The second wire circuit, however, is a nickel alloy conductor with a high positive temperature coefficient. In both devices overtemperatures are measured in the entire heated surface. Such units thus can be designed to develop upwards of 200 watts heating capacity, and still pass all the overtemperature tests described. These devices, however, make use of secondary circuit arrangements for the overtemperature protection. Hence, these secondary circuits must be judged as reliable and foolproof if the protection is to be considered adequate.

The first design described has a controller which thermostatically modulates the energy to the blanket according to the ambient room temperature. A normally open relay included in the controller is arranged to keep the unit energized, unless the leakage resistance in the blanket wire is diminished by excessive temperatures. The overtemperature circuit is, therefore, independent of the normal control operation, and is considered adequate if none of the circuit components may fail to cause its dangerous misoperation.

The second design mentioned has a controller which operates from the temperature sensitive conductor in the blanket to maintain a temperature which is comfortable to the user. As comfortable temperatures are much lower than any of the hazard temperatures outlined, the normal function of this arrangement limits temperatures in the blanket to safe values.

In operation the temperature sensitive nickel alloy wire is connected into the control unit as one arm of a wheatstone bridge. The resistance of the alloy conductor, therefore, is made a controller of the temperature within the blanket wire, and any changes in its temperature are reflected as changes in the output voltage of the wheatstone bridge. A 3-stage electronic amplifier is used to increase the bridge signal voltage and operate a 100-milliwatt relay which turns the heater circuit in the blanket on and off.

It is possible to devise a wheatstone bridge arrangement in which excessive temperature in the blanket or a broken blanket wire will disconnect the blanket. It is not so simple to devise a circuit in which failure of any of the components in the wheatstone bridge, its associated amplifier, or the relay circuit will de-energize the blanket. The foregoing conditions must be met, however, if the product is to be considered absolutely safe and dependable.

To accomplish these aims a common control circuit, as shown in Figure 3, is designed as follows. Increase in blanket temperature causes an increase in the resistance of the temperature sensitive conductor in the blanket. This, in turn, causes an increase in the output signal from the wheatstone bridge, and a decrease in the output of the first amplifier stage. When the first amplifier stage is off, the second amplifier stage operates at maximum conduction, and the third amplifier tube and the relay are off. To protect filament failures in the tubes, all filaments are connected in series and energized from a filament transformer. To protect against frozen relay contacts or failures of components in the second and third amplifier stages, a special *GL-1367* protective tube is used in the control. This gas-filled tetrode is made with double cathode tabs which act as fuse links in the blanket and control circuit. The plate of the tube is energized from the load contact of the relay and, therefore, is connected to the power supply only when the relay contacts are closed. The grid is supplied a negative bias from the output of the first amplifier stage. If the blanket is too hot, this bias is zero as outlined, and normally the relay will be open so the plate of the protective tube will not be energized. If the contacts of the relay freeze shut, or if components in the second and third amplifier stages fail causing the relay to remain closed, and develop excessive blanket temperatures, the plate of the *GL-1367* will be energized at a time when the bias on the grid is zero. The gas triode will conduct heavily (as its plate and cathode are directly connected across the power mains), and the cathode fuse tabs will blow out thus de-energizing the entire blanket circuit. The *GL-1367* protective tube described and the inherent circuit arrangement assure overtemperature protection in the event two of the bridge arm resistors open circuit, the filaments of the amplifier tubes fail, the second or third amplifier stages become inoperative, or in the event of a relay contact failure. Failure of the other bridge arm resistors or the first amplifier stage will cause heavy conduction of the first amplifier tube, to turn off the second amplifier stage. A small neon tube, therefore, is connected in the output of the first amplifier, so that excessive conduction of that tube will create across the plate load resistor of the first amplifier a voltage great enough to light the neon tube. The neon tube is so connected that current which it passes flows through a cathode resistor in the second amplifier circuit. Current flow through the neon tube causes a voltage drop in the cathode of the second amplifier to turn that stage "on" and the succeeding elements "off" in the event of failure in the first portion of the circuit. Although the electronic circuit described is the most complicated of all blanket control systems, it does give fundamental overtemperature protection and is devised to continue such protection in case any of the circuit elements fail.

CONCLUSIONS

This article has described the two principal hazards which may occur in an electrically heated blanket, specifications used by many testing agencies for evaluating these hazards have been detailed, and the design considerations necessary to meet these standards have been developed along with a discussion of common commercial products made today.

Probably the greatest weakness in present test standards is the evaluation of blanket use. There is still a divergence in the results of laboratory specifications and the practical difficulties which users experience. Time and continued research will close this gap.

New Turbine Plant

From three stories up, this is a view down on one of the largest bays in General Electric's new turbine building, the largest of its kind in the world. This bay is nearly 1/4 mile long, 80 feet wide, and 91 feet high. In the foreground, are some of the concrete pits for installations of machine tools, so arranged that a unidirectional flow of material is assured. At the top of the picture are two of the 51 traveling cranes. The capacity of the largest higher level crane is 200 tons with a clearance of 61 feet above the operating floor. The capacity of the largest lower crane is 100 tons. The new plant covers 20 acres of land and has more than a million square feet of floor space. Although the $30,000,000 building is not yet completed, limited production is being carried on in some sections. When in full operation, the plant will be capable of producing each month a quantity of turbines which could supply power and light for a city of over one-half million inhabitants

Papers Digested for Conference on Rubber and Plastics Industries

These are authors' digests of most of the papers presented at the second AIEE Conference on Electrical Engineering Problems in the Rubber and Plastics Industries, Akron, Ohio, April 26, 1949. These papers are not scheduled for publication in AIEE Transactions or AIEE Proceedings. However, they will be made available as a consolidated booklet at $3 per copy ($1.50 to AIEE members). Advance orders should be sent to R. S. Gardner at AIEE Headquarters, 33 West 39th Street, New York 18, N. Y.

Motor Requirements of Rubber Mill Drives; *R. S. Ferguson (Goodyear Tire and Rubber Company, Akron, Ohio).*

Power requirements of rubber mill machines keep increasing from year to year. This is particularly true of Banbury mixers. Twelve years ago size 11 Banburys were driven at 20 rpm with motors rated 250 horsepower or less. Now we are running them at 40 rpm with 600-horsepower motors and find that peak loads are in excess of 1,300 horsepower and average loads in excess of 700 horsepower. When the mixing time is short, the heating factor of a Banbury load cycle approaches 1.15. It is therefore incorrect to apply a service factor when choosing a motor rating for a Banbury drive. To take care of the heavy loads now experienced in Banbury operation, and also to allow some margin for still heavier loads which inevitably will be encountered in the future, it is recommended that 800-horsepower motors be installed on new Banbury drives.

Mill lines consisting of four 84-inch mills used to warm up tread stock have registered 30-minute demands as high as 730 horsepower. It is recommended that mills in such service be motored at the rate of 200 horsepower per mill. If this is done there will be a nine per cent margin to care for future increases in hourly production and stock toughness.

Maximum loads commonly encountered on tube machines may be expressed by the formula:

$$\text{Maximum horsepower} = 0.026D^2 \times \text{rpm}$$

D is the diameter of the barrel and rpm is the screw speed. This applies to tubers ranging from $2^1/_2$ inches to 12 inches in size. Loads are increased materially by the use of dies which are too small for the machine. For very constricted dies the constant in the formula is 0.03.

Maximum loads on 3-roll calenders in coating operations are 0.0075 horsepower per feet per minute per inch roll length. Since the advent of synthetic stocks the load when frictioning with a friction ratio of 1.52 to 1 is 0.018 horsepower per feet per minute per inch roll length.

Maximum loads on small 4-roll calenders when used to lay down gum strips on both sides of fabric stock may be expressed by the formula:

$$\text{Maximum horsepower} = 0.032 \times \text{feet per minute} \times \text{inches roll length}$$

Years of experience indicate that a safety stop of 14 inches roll travel may be obtained on a mill which is traveling at the rate of 100 feet per minute, providing a motor is selected which has a value of stored energy per horsepower which does not exceed 500 feet-pound.

Many d-c calender motors in the rubber industry have values of stored energy which are two or three times this amount when operated at top speed. For this reason safety stops on calenders are generally not nearly as good as those obtained on mills. Calender safety stops can be improved materially providing proper care is taken in planning the drive and in specifying the motor so as to obtain a low value of stored energy per horsepower.

Motor Drives for Banbury Mixers; *T. W. Millea (Farrel-Birmingham Company, Inc., Ansonia, Conn.).*

The standard Banbury has gears mounted directly on the rotors of the mixer. To accommodate higher than normal power a "uni-drive" which contains all reduction and connecting gears is recommended. The mixer rotors are connected to this separate sturdy drive by universal spindles.

Recommended specifications for sizes 1A, 3A, 9, and 11 mixers follow:

Single-Speed Mixers. Squirrel-cage motors; full voltage controls.

2-Speed Mixers. Without speed change during mixing—suitable for occasional change in speed. Squirrel-cage motors; full voltage controls.

2-Speed Mixers. With speed change during the mixing of each batch are special applications and recommendations will depend on power system limitations and proposed operating procedures.

Motors. Continuous duty, 125 per cent starting torque, not less than 250 per cent maximum running torque, service factor 1.15. The electrical industry has recognized the severity of Banbury service by building "rubber mill" type motors having extra heavy rotors, specially braced stators, and special insulation treatment.

Enclosed Motors. Recommended where excessive dust, carbon black, plasticizers, or solvents exist in atmosphere.

2-Speed Motors. The trend is toward single-speed mixers however, if two speeds are required, dual motor drives are worthy of consideration.

Brakes. Not required.

Controls. Full voltage, magnetic. Reversing is required.

Important Note. If full voltage starting of squirrel-cage motors is prohibited, wound-rotor motors are recommended as good starting torque is essential.

Short-Circuit Protection. Low voltage—circuit breakers; high voltage—current limiting fuses.

Accessories. Operator's panels with heavy duty accessories.

Synchronous Motors. If user insists on a synchronous motor for plant power factor correction, we recommend a torque rating of 125 per cent starting, 100 per cent pull-in, 250 per cent pull-out; and full voltage starting.

Operating Suggestions:

1. Operate mixer within power limit of motor.
2. Consider automatic control of ram pressure to prevent stalling.
3. Avoid frequent stops and starts.
4. Avoid frequent speed changes. Change speed with mixer empty.
5. Start motor with mixer empty.
6. Lubricate all equipment adequately.
7. Keep equipment clean.
8. Avoid jogging if mixer stalls. To restart a stalled mixer we recommend that after relieving the ram pressure the mixer should be run in reverse for about 30 seconds and then run forward.
9. Allow only competent men to control the motor.

The Application of Electric Motor Drives to Rubber Mills; *William S. Watkins (The Ohio Rubber Company, Willoughby, Ohio).*

The 2-roll mill is the most generally used machine in the rubber and plastics industries, both as to variety of function and number of units in service. Consequently, it is important that no factor be overlooked in applying motor and control which will enable the machine to perform required functions economically and effectively, with adequate provision for possible future needs.

A check-sheet is suggested which lists in a systematic form all of the determinants which influence the selection, and all possible alternatives which might become part of the specification. Starting with the function of the proposed machine, the check-sheet breaks down the factors as fundamentally as possible. Basic mechanical conditions to be encountered, range of materials to be processed, speed requirements, power and torque characteristics of the load are typical headings which summarize data in an outline form, which makes the final determination less complex and more accurate.

Empirical formulas for predicting power and torque can be evaluated in terms of known quantities, supplemented by experiment. For example, horsepower can be estimated by the formula

$$\text{Horsepower} = K \times \text{feet per minute} \times \text{roll face in inches} \times \sqrt[3]{\text{friction ratio}},$$

where K varies between 0.015 and 0.035 and is determined from existing installations or trials on laboratory mills.

The benefits of standardization are not to be ignored, and in the matter of motor torques, for instance, the wide acceptance of standard values at start, pull-in, and pull-out of 125 per cent, 125 per cent, and 250 per cent respectively, is welcomed. The check-sheet should serve to point out, however, that under certain conditions nonstandard values may be more nearly correct. Refiners may require higher starting and pull-in torques and certainly do not require 250 per cent pull-out value, whereas crackers and breakdown mills usually do not need the standard starting torques but may require higher pull-out or maximum torque.

The question of high-speed motor with gear reducer versus low-speed motor should not be brushed aside, as the check-sheet will show certain definite advantages for each arrangement.

The scientific method dictates that questions must be analyzed without any preconceived notions or opinions, so for any application all types of motors and all means of braking should be considered, in spite of the fact that most applications seem to call for a certain "favorite" type. It is also most important to check each application for unusual requirements in duty cycle, and to make sure that the most economical mechanical modifications, such as enclosures, bearing types, and the like, are selected.

Control for mill motors is worthy of scrutiny because it represents a large part of the cost of the drive, and is most apt to cause trouble in operation. Such matters as short-circuit protection, means of arc suppression, and location of control require careful study.

When all of these factors have been given appropriate weight, and the new application plotted as part of the plant power system, the engineer can rest assured that the drive specified will be the best for the job.

Motor Drives for Calenders; *V. O. Johnson (United States Rubber Company, New York, N. Y.).*

The problem of motor selection for calenders is amplified by the great variety of calender sizes and calender processes. Calender loads are influenced by the condition of the stock, method of feeding, and adjustments, as well as calender size and speed. The motor rating should be based on the worst condition to be expected in normal operation. The relation between power and speed is expressed most correctly by an exponential function, but the assumption of a linear relation may be made for the purpose of a study of motor requirements. The standard tapered rating for adjustable speed d-c motors, as specified in "NEMA (National Electrical Manufacturers Association) Motor and Generator Standards" provides a higher torque rating at low speed than at high speed, while the linear relation of power to speed is the condition of constant torque.

The maximum power requirement for any given calender process may be shown in graphical form as a function of speed. The following equation for maximum power may be used:

Horsepower = constant $(K)\times$roll length (inches)$\times$roll surface speed (feet per minute

The constant (K) may be expressed as the ratio of power to the product of roll length and speed. It has the dimensions of torque per unit length of roll face and is proportional to the slope of the horsepower curve. Since adjustable-speed d-c motors are not constant torque machines, a constant (K) may be computed for any given speed such as base speed or top operating speed. If the K for the process is known, it is easy to determine whether a given motor is suitable at all speeds or what part of the speed range may be covered. Motor and gear rating computations may be made and shown graphically as a function of speed. Co-ordination of motor and gear ratings may be studied. Adjustable voltage motor ratings bear a closer relation to gear ratings and calender loads than do constant voltage ratings. Adjustable voltage drive has other advantages such as wider speed range, improved braking, and smoother starting.

The problem of braking and safety stops requires attention to details of construction and location of safety switches and other safety features of a calender. The measurement of stopping distance of calenders or mills may be simplified by the use of a new instrument. It consists of a rubber-covered wheel riding on the calender roll, that by means of a cam-operated switch opens the safety circuit and automatically indicates the stopping distance with an accuracy of ±0.1 inch. The instrument is very useful to engineering departments for checking the results of adjustments intended to improve the stopping distance.

Joint Industry Conference Electrical Standards Viewed by an Equipment Manufacturer; *Thomas C. Jones (National Rubber Machinery Company, Akron, Ohio).*

Considering the adoption of the Joint Industry Conference Electrical Standards by the equipment manufacturers of process machinery for the rubber and plastics industry, may we confine our thinking to the smaller equipment where the controlling devices will be an integral part of the machine. Here falls a large percentage of standard line machinery as well as special equipment built to a customer's specifications. In this field a definite advantage can be shown by applying the improved techniques of electrical construction and wiring covered by these standards.

In recent years the industry is using more and more complex electric controlling devices to improve the efficiency of processing equipment, with the result that electrical maintenance problems have increased. It is only logical some electrical standards should be adopted which will give basic control of these problems.

The manufacturing of equipment for the rubber and plastics industry is very competitive, and the industry itself builds a large number of its own machines. Therefore, the selling price as well as the quality must be competitive or one equipment is not sold. Until the industry as a whole accepts these standards, equipment manufacturers must be cautious in acceptance of the Joint Industry Conference Standards until a definite trend can be forseen.

To sum up the advantages to be gained by the adoption of the Joint Industry Conference Standards, and to reap the full benefits, we all must consider the adoption of these Standards favorably on all equipment, whereby all will be on equal footing and will be able to give the industry the electrical qualifications needed to maintain the high production on which our standard of living depends.

Motor Requirements for Tuber Drive; *D. J. Rose (The Firestone Tire and Rubber Company, Akron, Ohio).*

Range of products run on a single tuber are such as to require adjustable speeds with fairly wide range for smaller plants and somewhat narrower range for large plants having many tubers. We are coming to believe that of all the types of adjustable speed drives available, single-voltage d-c motors with necessary field range offer the best present solution to tuber drive problems. The over-all economy of the drive—supply combination, when considered in connection with other plant d-c needs, is attractive. Also, the inherent characteristics of such motors are best suited to over-all tuber drive requirements.

The concept of tubers as machines requiring essentially constant torque drives is true for a given single set of conditions of stock stiffness and die size. At a given speed different stocks and dies result in more or less power required. Since the motor must be capable of driving the tuber through its speed range under all probable conditions of stock plasticity and die size, we gain by considering the requirement as essentially constant horsepower. Adjustable voltage, dual voltage d-c motors, or adjustable speed a-c motors are likely to be overloaded at lower speeds under some conditions. We consider the tubers' range of products is extended, through use of constant horsepower motors, beyond the range permitted by any other type of drive.

Rubber and plastics industry engineers have comparatively little real knowledge concerning pressures developed within the tuber during operation, or the effect of varying conditions of speed, plasticity, and die opening upon these pressures and resultant power requirements. Reasoning and observation of tubers in operation lead us to believe that for any stock there is a definite maximum to the pressures that will be developed. We believe that these pressures are dependent upon the ability of the stock to resist slippage on the barrel or screw surfaces. This ability is responsible for the progress of the stock through the machine. Increasing speed or decreasing die opening will cause pressure and power input increase up to a definite point at which point stock begins to slide around within the barrel with the screw with power input dropping off. Of the resultant power input observed, only a portion is required to maintain motion of the body of stock once slippage has started. Balance of power used is expended in working or milling the small quantity of stock between screw end and die face, with resultant high temperatures being observed. That head pressures are comparatively light under these conditions is obvious by reason of the slowness with which the stock emerges through the restricted die opening.

We find that there is no use attempting to use dies with too small relative openings or run the screw at too high relative speeds. Tubers will fulfill maximum production needs only when speeds and die sizes permit operation with minimum stock slippage on internal surfaces. Under such conditions only can motor loads be evaluated accurately in terms of production and calculations by the formula

Horsepower $= KD^2$ (rpm)

be made to apply to tuber drives with expected accuracy.

1948 Rubber and Plastics Booklet Still Available

The papers and discussions presented at last year's Conference on Electrical Engineering Problems in the Rubber and Plastics Industries, which took place in Akron, Ohio, April 20, 1948, still are available in a consolidated pamphlet which may be obtained from the AIEE Order Department, 33 West 39th Street, New York 18, N. Y. Prices are $3 per copy to nonmembers; $1.50 per copy to AIEE members.

INSTITUTE ACTIVITIES

The Report of the Board of Directors of Our Institute for the Year Ending April 30, 1949

A Message From the President

This is the 65th year of our Institute. Our Founders opened a door and electrical engineers have advanced electricity into every available avenue for the service of mankind.

We had 30,791 members as of April 30, 1949, an increase of 2,391 members for the year, which is most substantial. Also, we had 18,700 Student Members just before graduation this year. When you received your issue of *Electrical Engineering* for April 1949, you could say that it was being received by 52,100 other electrical engineers and students and subscribers in the United States, Canada, Mexico, and all over the world, a great power of electrical engineering knowledge for great good to the advancement of electricity the world around.

We had 84 Sections in our Institute and 129 Student Branches, April 30, 1949. Here are our members in their electrical engineering lives as they regularly assemble for advancement in the theory and practice of electrical engineering and of the allied arts and sciences, and of the maintenance of a high professional standing. This year 128,025 attended 1,561 Section meetings, an increase in attendance at meetings of seven per cent over last year, and 103,828 attended 1,350 Student Branch meetings, an increase in attendance at meetings of 34 per cent over last year. This attests to the increasing vigor of electrical engineering participation in the advancement of electricity for the use and the service of mankind. Our new Sections this year were Richland, Wash., Niagara International, and Miami, Fla., and our new Student Branches at Louisiana Polytechnic Institute, and at Fenn College, Cleveland, Ohio. We are happy that this Section and these Student Branches have been added to our Institute.

Our finances are in good shape. We are operating on a balanced budget in the budget year ending September 30, 1949. The excess of expenditures over income for the fiscal year ending April 30, 1949, is approximately $18,000, which is some $27,000 less than for the previous fiscal year.

Our technical committee activities which are the heart of our Institute have been expanded appropriate to the expanding avenues of electrical engineering advance. We now have 38 technical committees, with these eight new committees:

Committee on Wire Communication Systems
Committee on Radio Communication Systems
Committee on Aural Broadcasting Systems
Committee on Television Broadcasting Systems
Committee on Telegraph Systems
Committee on Communication Switching Systems
Committee on Special Communication Applications
Committee on Metallic Rectifiers

Also, an organization of co-ordinating committees appropriate to progressing the technical activities expeditiously has been established. The activities of these technical committees are reported in the report of the Board of Directors presented at our annual meeting in June, and to be published in the August 1949 issue of *Electrical Engineering*.

The papers presented at our general and District meetings as the contributions of our technical committees to electrical engineering progress will be, as approved, contained in our *Transactions* of electrical engineering history throughout our 65 years of technical contributions to the service of man as there has been made available to him the products and the services of electricity.

Our newest feature for the advancement of new knowledge to a greater number of our members are the special technical conferences. These are conferences under the auspices of technical committees. Any technical committee can hold a special technical conference by obtaining clearance of its co-ordinating committee and headquarters that the desired conference date, presents no conflict. The technical conferences held this year have been:

Conference on Electronic Instrumentation in Nucleonics and Medicine, Nucleonics Committee joint with Institute of Radio Engineers and New York Section, New York, N. Y., attendance 547.

Conference on Electric Welding, Committee on Electric Welding, with Michigan Section, Detroit, Mich., attendance 436.

Conference on High-Frequency Measurements, Instruments and Measurements Committee joint with Institute of Radio Engineers and National Bureau of Standards, Washington, D. C., attendance 584.

Conference on Industrial Application of Electronic Tubes, Electronics Committee joint with Industrial Control Committee and Niagara Frontier Section, Buffalo, N. Y., attendance 238.

Conference on Electrical Engineering Problems in Rubber and Plastics Industries, General Industry Applications Committee with the Akron Section, Akron, Ohio, attendance 195.

Another outstanding event this year has been in the Committee on Public Relations with a program to reflect our Institute's position of responsible leadership in the scientific and engineering world and as the authoritative source of information regarding broad advances in the art of electrical engineering. The Sections are in strategic position to bring to the local press the rightful position of the electrical engineer as he makes available to his fellowmen the electric products for his enjoyment and use and the electrical services to make life happier. To this end a "publicity kit" has been designed available to the Section. This is an opportunity to bring to the engineer the recognition from the contributions he has made. Our Sections should use it for great good.

With it we continually have made the point this year throughout the Sections and the Student Branches that each electrical engineer has it within his own power to bring recognition to himself if he will but work with his fellowmen in his community—where he will become known because of his contributions, and where he will come into personal contact with the public to bring the name of the engineer into more frequent statement and knowledge. That this is going on everywhere by engineers, I have found. That it may well be emulated by more engineers, particularly those who have not been so doing, I am convinced will be for great good. This will advance the professional estate of which Mr. Wilson spoke at the Winter General Meeting of our Institute (*EE, Mar '49, pp 187–90*) in most effective measure.

The report of your Board of Directors rings with further service. To read of the honors brought to our fellow electrical engineers emphasizes their services rendered to the good and to the enjoyment of mankind. To recognize that we have 40 representatives in different technical activity interests outside of our Institute reveals the extension of technical activity into every phase of man's life, to undergird the great industries in our land, the far-flung agriculture, our government, and the engineering schools of our land. Here especially is our Engineers Council for Professional Development accrediting program at work to maintain our educational standards high in our profession, and to bring to the students who are being graduated into the profession the advances in knowledge which have come from the scientific and engineering advances of our day and time, advances which have been the wonder of man. We owe much to those who are giving of their time to our ECPD work.

And as we read the list of our members who have been taken from us by death, we pause in our busy life to rethink of them in their life contributions of service to their fellowmen.

Thus I trust that as each member of our Institute reads the report of our Board of Directors for the year, he may be inspired to see beyond the details which it records, the greatness of the contributions of our members to the educational and scientific interest of every member that each will have been a better electrical engineer at the end of the year than he was at the beginning. This is our great strength.

U. S. Navy official photo

The San Francisco Naval Shipyard at Hunters Point will be inspected during the AIEE Pacific General Meeting, to be held in San Francisco, Calif., August 23–26, 1949

Pacific General Meeting to Feature Transportation

The 1949 Pacific General Meeting, to be held in San Francisco, Calif., from August 23 to 26, will strike a contrast between old and new modes of transportation. The meeting will be held on the 100th anniversary of the great "California Gold Rush." At that historical time, long covered wagon trains made their trek across the continent. Contrasted with this pioneer transportation means, the Pacific meeting will emphasize air travel in a series of air transportation conferences, one to be held on each day of the meeting. All phases of electricity in aircraft will be covered.

In addition to a full program of technical papers, other events of special interest will be the inspection trips to industrial installations in the San Francisco Bay area. The San Francisco Naval Shipyard at Hunters Point will be host to the AIEE on Thursday, August 25. The world's largest naval drydock will be included in the inspection. Several of the new multimillion dollar projects of the Pacific Gas and Electric Company will be visited. On the schedule are Station P, new 220,000-kw generating station; Mission Station, 110,000-volt indoor substation in the heart of the city; and the new modern a-c calculating board.

An inspection trip is planned at the Ames Aeronautical Laboratory at Moffett Field, where several gigantic wind tunnels are in operation. Also to be visited is the Radiation Laboratory at the University of California where the world's largest cyclotron is located. A trip will be made to the new tinplate mill of the Columbia Steel Company at Pittsburg, Calif.; and visitors will be welcomed at the newly completed 17-story telephone equipment building in Oakland.

The ladies' program has been planned carefully. There is to be an informal tea, a trip to Palo Alto and Stanford University, a tour of San Francisco and Chinatown, and a boat trip on San Francisco Bay.

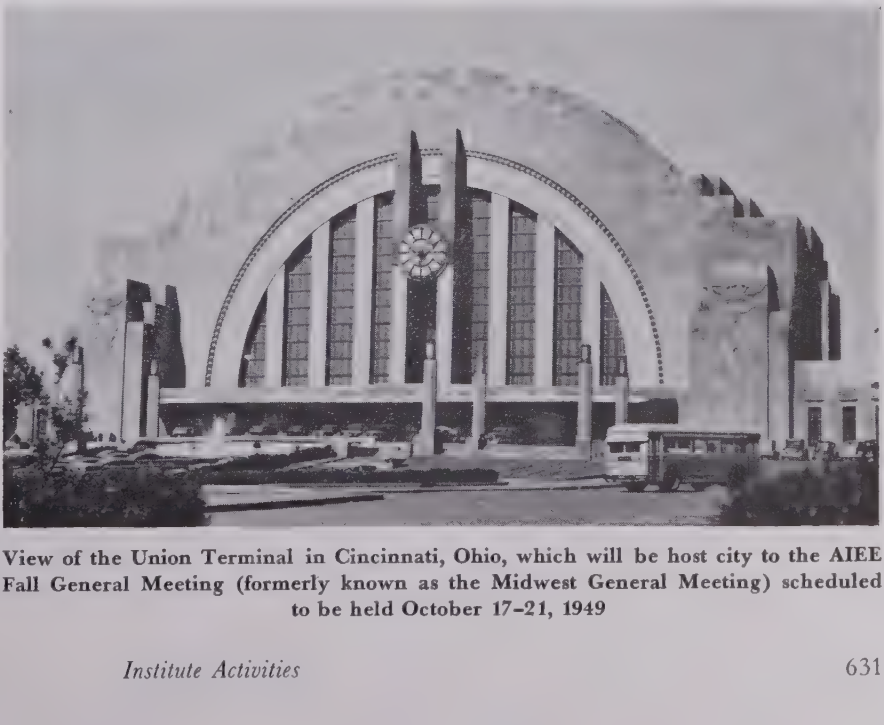
A highlight of the entertainment program will be the banquet on Thursday evening. The dinner will be followed by a show featuring stage and radio stars.

Additions to List of Members-for-Life

Membership for life is granted by the AIEE to members who either have paid annual dues for 35 years, or have reached the age of 70 and paid dues for 30 years. A list of those who have become Members-for-Life during the preceding year is published annually in *Electrical Engineering*. Institute members who attained this status on May 1, 1949, are

Albright, A. S.
Allen, H. V.
Allum, J. A. C.
Applegate, K. P.
Atwood, E. H.
Augustine, P.
Bailey, E. L.
Barns, B. L.
Bearce, W. D.
Beaver, J. L.
Benzing, H. J.
Blaisdell, J. L.
Bose, S. N.
Brackett, H. H.
Buckard, C. A.
Bundy, E. S.
Bundy, O. H.
Calland, O. G.
Carr, E. C.
Christensen, C. P.
Collins, E. W.
Connell, E. L.
Crothers, H. M.
Curtner, D. L.
Davidson, W. F.
Dexter, H. E.
Dinion, N.
Dorting, E. E.
Douglas, J. F. H.
Dover, A. T.
Duncan, T. C.
Edwards, I. W.
Eidam, E. G.
Eves, Wm., III
Faught, R. C.
Fawcett, C. D.
Fellows, W. H.
Fetherstonhaugh, E. P.
Field, C.
Field, H. H.
Fisher, R. B.
Flanders, M. M.
Fondiller, W.
Fraser, D. M.
Gardner, J. E.
Gilbert, J. J.
Gill, M. F.
Gillespie, F. M.
Gillett, O. G.
Grant, L. S. F.
Grimsdick, E. P.
Hague, F. T.
Harbin, G. F.
Harvey, R. J.
Hellenthal, J.
Hentz, R. A.
Herbst, W. B.
Herrlich, H. W.
Hickok, R. D.
Hitchcock, E.
Holmes, H. A.
Humphrey, H. K
Jackson, N.
Jacobs, E. H.
Jefferson, W. H
Johnson, F. E.
Jones, F. S.
Jones, R. L.
Kennedy, C. L.
Kent, W.
Kerr, B. W.
Kester, C. D.
King, G. A.
King, R. P.
Kingsland, R. L.
Kirkwood, M.
Knutz, W. H.
Kostko, J. K.
Kriegsmann, A. E.
Kutner, S. D.
Lapp, J. S.
Lautrup, G.
Lawson, J. T.
Lidbury, F. A.
Lix-Klett, E.
Lockwood, A. M.
Long, C. C.
Lowe, H. L.
MacCutcheon, A. M.
McKavanagh, T. J.
MacTavish, H. J.
Mahan, J. S.
Marshall, R. C., Jr.
Marshick, O. J.
Martin, W. H.
McClain, J. R.
McClellan, L. N.
McMaster, R. K.
McMillan, F. O.
McNeill, R. W.
Melvin, H. L.
Meyer, A. A.
Mittag, A. H.
Mommo, E. J.
Montsinger, V. M.
More, C. H.
Morrison, G.
Morton, R. B.
Muller, H. N.
Mulrony, M. A.
Munroe, R. B.
Neblett, H. W.
Neild, J. F.
Oldacre, M. S.
Overocker, R. H.
Patterson, J. G.
Peters, J. F.
Pikler, A. H.
Pillsbury, E. S.
Powers, A. R.
Prescott, R. D.
Ramsey, H. E.
Rennie, W. M.
Rice, C. W.
Richey, A. L.
Riley, G. A.
Roosevelt, J. K.
Ross, R. J.
Ruhling, T. C.

Fall Meeting Set for Cincinnati



View of the Union Terminal in Cincinnati, Ohio, which will be host city to the AIEE Fall General Meeting (formerly known as the Midwest General Meeting) scheduled to be held October 17–21, 1949

Sanford, D.
Schaefer, C. C.
Schoolfield, H. H.
Shaw, T.
Smith, H. K.
Smith, W. V.
Stafford, H. E.
Stair, J., Jr.
Sultzer, M.
Talbot, H. L.
Taylor, A. H.
Tea, P. L.
Thiele, E. J.
Thomas, B. F., Jr.
Thompson, R. E.
Thomson, G. L. A.
Toomey, J. F.
Townsley, F. P.
Traynor, P. W.
Uhlendorf, E. D.
Weiss, F. C.
Wheelock, J. F.
Woodman, F. W.
Woolfson, M. G.

Second Rubber and Plastics Conference Held in Akron

A highly successful AIEE Conference on Electrical Engineering Problems in the Rubber and Plastics Industries attended by some 191 technical specialists was held on Tuesday, April 26, 1949, at the Hotel Portage in Akron, Ohio. Seventh in the series of AIEE technical conferences, this was the second covering the field of rubber and plastics electrical problems. As before, the conference was sponsored by the AIEE Subcommittee on Rubber and Plastics Industries of the AIEE Committee on General Industry Applications, and the Akron Section of AIEE acted as host to the conference.

Ten papers were presented at the conference; five on motor drives, one on preventive maintenance, and four on various aspects of the Joint Industry Conference Electrical Standards for Industrial Equipment. A complete program of the conference appeared in the April issue of *Electrical Engineering* (*EE, Apr '49, p 352*). The sessions began at 8:30 in the morning, were adjourned for lunch at 12:30, and the conference was concluded at 4:30 in the afternoon. (Digests of most of these papers appear in this issue on pages 628–9).

Following the general sessions, the AIEE Subcommittee on Rubber and Plastics Industries held a meeting to discuss the conference and to plan for future activities. In general the committee was satisfied with the conference, the facilities available were good, and the meeting proceeded smoothly.

In considering plans for a 1950 conference, the committee felt that having a meeting on a Friday and the following Saturday morning would be desirable. More time would be available for papers and discussions with this arrangement. The choice of related papers in groups rather than unrelated papers on diversified subjects for the conference just concluded was considered a good one. It was planned to continue this practice for the 1950 conference. W. J. Secres and R. F. Snyder were appointed by Chair man K. W. John to form a working group, to be assisted by others according to their choice in order to accomplish the following objectives: to obtain electrical data on recent installations on tubers, mills, calenders, and Banburys for use in future papers on rubber mill drives; and to review Joint Industry Conference Electrical Standards and how the rubber and plastics industries may profit by the general adoption (modified, if required) of these standards.

At the close of last year's conference all the papers presented with their related discussions were compiled into a booklet that subsequently was made available for a nominal fee. This same procedure is being followed for this year's conference. G. V. Kullgren has been appointed to edit the 1949 booklet, and it is expected to become available in the near future. Advance orders for the 1949 booklet, together with remittance ($3, $1.50 to AIEE members), should be sent to R. S. Gardner, AIEE Headquarters, 33 West 39th Street, New York 18, N. Y. A limited supply of the booklet covering the papers and discussions of the 1948 conference entitled "Electrical Engineering Problems in the Rubber and Plastics Industries" still is available. Orders for this publication, together with remittance ($3, $1.50 to AIEE members), should be sent to the AIEE Order Department, 33 West 39th Street, New York 18, N. Y.

The successful planning and completion of the conference was the result of the cooperative efforts of the AIEE Subcommittee on Rubber and Plastics Industries and various members of the Akron Section of AIEE. Personnel on the former group include:

K. W. John, *Chairman*, A. T. Bacheler, B. J. Dalton, J. A. Geinger, V. O. Johnson, G. V. Kullgren, J. F.

Attending a meeting of the AIEE Subcommittee on Rubber and Plastics Industries during the April 26 conference in Akron, Ohio, were the following subcommittee members, and others as indicated. Beginning in center foreground, with person looking towards right, and continuing clockwise, are shown: G. V. Kullgren, Adamson United Company, Akron, Ohio; C. E. Robinson, Reliance Electric and Engineering Company, Cleveland, Ohio; J. F. Moore, Dunlop Tire and Rubber Company, Toronto, Ontario, Canada; B. D. Morgan, Johnson and Johnson, New Brunswick, N. J.; V. O. Johnson, United States Rubber Company, New York, N. Y.; K. W. John (Subcommittee Chairman), United States Rubber Company, Detroit, Mich.; W. J. Secrest, Firestone Tire and Rubber Company, Akron, Ohio; R. F. Snyder, Goodyear Tire and Rubber Company, Akron, Ohio; L. A. Umansky (Chairman, AIEE Committee on General Industry Applications), General Electric Company, Schenectady, N. Y.; B. J. Dalton, General Electric Company, Schenectady, N. Y.; R. S. Gardner, Assistant to AIEE Secretary, AIEE Headquarters, New York, N. Y.; W. L. Ringland, Allis-Chalmers Manufacturing Company, Milwaukee, Wis.; A. T. Bacheler, Westinghouse Electric Corporation, East Pittsburgh, Pa.; H. G. Shively (Akron Section member), B. F. Goodrich Company, Akron, Ohio

Future AIEE Meetings

Pacific General Meeting
Fairmont Hotel, San Francisco, Calif.
August 23–26, 1949
(*Final date for submitting papers—closed*)

Fall General Meeting
Netherland Plaza Hotel, Cincinnati, Ohio
October 17–21, 1949
(*Final date for submitting papers—July 19*)

Winter General Meeting
New York, N. Y.
January 30–February 3, 1950
(*Final date for submitting papers—November 1*)

North Eastern District Meeting
Providence, R. I.
April 26–28, 1950
(*Final date for submitting papers—January 26, 1950*)

Great Lakes District Meeting
Jackson, Mich.
May 11–12, 1950
(*Final date for submitting papers—February 10, 1950*)

Summer and Pacific General Meeting
Huntington Hotel, Pasadena, Calif.
June 12–16, 1950
(*Final date for submitting papers—March 14, 1950*)

General scene at the Conference on Electrical Engineering Problems in the Rubber and Plastics Industries, held at the Hotel Portage, Akron, Ohio, on April 26, 1949

Moore, B. D. Morgan, W. L. Ringland, C. E. Robinson W. J. Secrest, H. L. Smith, R. F. Snyder

In the latter group, C. R. Reid, P. S. Bechtol, J. R. Dorsey, and all other members of the Akron Section of AIEE who assisted in the preparation of the meeting were voted special thanks by the Subcommittee on Rubber and Plastics Industries.

Middle Eastern District Holds Prize Paper Contest

With 19 Branch prize winners participating, the AIEE Middle Eastern District (2) held its District Branch Prize Paper Competition for 1949 at the Carnegie Institute of Technology, Pittsburgh, Pa., April 29–30. The event was under the chairmanship of M. W. Slye, Chairman of the Carnegie Branch, while Dr. E. M. Williams, Counselor, and students of the Carnegie Branch were responsible for arranging the meeting.

Presentation of the papers were scheduled for Friday and Saturday mornings, and on Friday afternoon the contestants were guests of the Westinghouse Electric Corporation at a luncheon and tour of the Westinghouse plant. Certificates of Awards and ten dollar checks were presented to each Branch prize winner by District Secretary A. C. Muir at a dinner for the contestants, Counselors, judges, members of the Pittsburgh Section, and students, which was held on Friday evening in the Carnegie Student Union. The dinner was followed by an inspection of Machinery Hall where the Electrical and Mechanical Engineering Departments of the school held "Open House." Luncheon on Saturday was held at the Skibo Inn, and on Saturday afternoon an inspection was made of the University of Pittsburgh Cyclotron Laboratory.

First prize in the competition, $25 and a Certificate of Award, went to Richard W. Sonnenfeldt of the Johns Hopkins University for his paper, "A New Method for the Rapid Tracing of Concealed Conductors and Location of Faults," which described an interesting and original method for the location of fault in concealed conductors in large buildings. Honorable Mentions were awarded to Donald M. Berk, Jerome A. Sader, and Herbert Epstein. In addition, H. R. Ryerson won first prize of five dollars and M. Dodak won second prize of a "radar chassis" for the best discussion questions for Friday morning, while Herbert Epstein and William Klein, respectively, won similar prizes for the best discussion questions for Saturday morning. The discussion awards were contributed by the Carnegie Student Branch.

The 19 Branch prize winners who took part in the competition, and the titles of their papers, were

"Bridge Circuits," James W. Jones, University of Akron

"Some Recent Advances in Industrial Radiology," Wesley G. Nilson, Bucknell University

"Mecho-Electronic Phone Pickup," James R. Horsch, Carnegie Institute of Technology

"Electricity in Electroplating," Curtis K. Smoyer, Catholic University of America

"Methods of Indicating Phase Displacement," Marshal M. Carpenter, Jr., University of Delaware

"The Mechanical Converter," Carl E. Gryctko, Drexel Institute of Technology

"Ward-Leonard Speed Control," Otto R. Beck, Fenn College

"A Survey of Servomechanisms," William J. Klein, George Washington University

"A New Method for the Rapid Tracing of Concealed Conductors and Location of Faults," Richard W. Sonnenfeldt, Johns Hopkins University

"On the Fringe of Television," Donald M. Berk, Lafayette College

"Some Typical Characteristics and Applications of a Thermistor," James H. Vogelsong, Lehigh University

"Microwaves—Development and Usage," Gordon Frye, Ohio Northern University

"Push-Push Thyratrons as Controlled Rectifiers," Michael Dodak, Ohio University

"The Germanium Triode," George John Hasslacher III' Pennsylvania State College

"Electric Theory of Nerve Excitation," Herbert Epstein, University of Pennsylvania

"Atomic Power for Electric Energy," Jacob Katz, University of Pittsburgh

"Potential Field Calculation by an Analogy Method," Thomas B. Bissett, Princeton University

"The Load Center Distribution System," Jerome A. Sader, Swarthmore College

"A Proposed System for Checking Distribution Transformers," Olin Compton, West Virginia University

The Prize Paper Judging Committee, which was appointed by the District Co-ordinating Committee, consisted of Homer Wagner, Leo J. Berberich, L. N. Grier, and Dr. G. M. Anderson, acting as Secretary.

Arrangements, hotel reservations, and other details of the meeting were handled by the Student Branch under the supervision of M. W. Slye and Robert Anguish, Social Chairman.

Student members, Branch prize winners, Counselors, and District officers at the District 2 Branch Prize Paper Competition, Carnegie Institute of Technology, Pittsburgh, Pa., April 29–30, 1949

President-Elect Fairman Addresses N. J. Division of N. Y. Section

A talk by AIEE President-Elect James F. Fairman highlighted the dinner held by the New Jersey Division of the AIEE New York Section in combination with an inspection trip to the Bell Telephone Laboratories, Murray Hill, N. J., on May 27, 1949.

The inspection trip consisted of a conducted tour to six points of interest in the laboratories followed by short talks by several prominent Bell Telephone engineers on subjects of current interest such as the transistor. In his address at the dinner, which was held at the Hotel Suburban in Summit, N. J., Mr. Fairman stressed the endeavor to be made in the coming year to organize a definite program for the advancement of the engineering profession and improvement in the status of engineers.

The combined inspection trip and dinner was attended by 132 persons. Among those present was the new chairman of the New York Section, D. W. Taylor. The retiring chairman of the New Jersey Division, Lawrence J. Lunas, introduced the incoming executive committee of the New Jersey Division which will be headed by James S. Bell as chairman.

Middle Atlantic Section Holds Spring Meeting at West Point

The spring meeting of the AIEE Middle Atlantic Section was held at the United States Military Academy at West Point, N.Y., on Saturday, May 14, 1949. Professor R. T. Weil, head of the Department of Electrical Engineering at Manhattan College, Riverdale, N.Y., presided as chairman of the conference.

Major General Bryant E. Moore, Superintendent of the United States Military Academy, delivered the address of welcome. He was followed by Colonel B. W. Bartlett, head of Department of Electricity at West Point, who discussed the mission, curriculum, and teaching methods of electrical engineering schools. In addition, Major General K. D. Nichols, Chief, Armed Forces Special Weapons Project, presented an address on "Education for Nuclear Engineering." Other features included demonstrations covering steam, gasoline, and jet engines; refrigeration; friction losses in orifices; weir calibration; and impulse turbines; discussions of military topography and graphics, including surveying, map making, air photo interpretation, and military photogrammetry; and a conducted tour through the Ordnance Laboratories arranged by the Department of Ordnance at West Point.

Maryland Section Conducts Student Prize Papers Contest

The Student Prize Papers Contest conducted by the AIEE Maryland Section was held at Johns Hopkins University, Baltimore, on Tuesday, May 17, 1949.

In following its time-honored custom of having periodic contests for prize paper compositions, the Maryland Section decided, in the interest of encouraging the young engineers who had not yet graduated, to limit the Prize Papers Contest this year to Student members.

The names of the winners, the titles of the papers they prepared, and the awards they received follow: *First*, Richard Sonnenfeldt, "A New Method for the Rapid Tracing of Concealed Conductors and Location of Faults," desk pen set (with figure); *second*, Henry C. Hoffman, "The Cathode-Ray Tube and Its Application to the Oscillograph," desk ash tray (with figure); *third*, James F. O'Neill, "The Seeing-Eye of Radar," trophy (with figure). Each award was suitably inscribed.

In addition to these prizes, the winner of the first prize, Mr. Sonnenfeldt, received from Institute headquarters the Branch Prize of $10. As winner of the Maryland Section contest, he presented his paper in a Middle Eastern District contest, the District comprising the states of Ohio, Pennsylvania, West Virginia, Maryland, Delaware, and New Jersey, at a meeting in Pittsburgh, Pa. There he was awarded the District Branch competition prize of $25.

The three winners at present are attending Johns Hopkins University.

Philadelphia Section Holds Annual Prize Papers Night

At its final meeting of the 1948–49 season, the AIEE Philadelphia Section held its annual "Prize Papers Night." The winning papers in the Section competition were presented by their authors at the meeting, and first honor awards of $25 each were given for the following papers:

Power Systems. "Transient and Cyclic Load Temperature Calculations for Cable Systems," by J. H. Neher, Philadelphia Electric Company

Electronics and Communications. "Automatic Range-Adjusting Radio Sonde Recorder," by G. E. Beggs, Jr., Leeds and Northrup Company

Instruments and Measurements. "Graphical Method for Estimating the Performance of Distance Relays During Faults and Power Swings," by A. R. Van C. Warrington, General Electric Company

Basic Sciences. "Design of a Digital Computing Machine," by T. K. Sharpless, Technitrol Engineering Company

Student Papers. "Method of Indicating Phase Displacement Between Periodic Electrical Waves," by M. M. Carpenter, Jr., University of Delaware

M. M. Carpenter, Jr., of the University of Delaware, also was awarded a special prize of ten dollars for the best presentation.

St. Louis University Senior Wins St. Louis Section Award

Clemens Deck, formerly a senior in the St. Louis University Institute of Technology, St. Louis, Mo., was awarded first prize in a recent statewide contest for undergraduate students of engineering sponsored by the St. Louis Section of the AIEE. Mr. Deck was awarded his degree in electrical engineering in June.

The winning paper, entitled "Light Slave," described a self-contained electric device for firing a remote flash bulb when actuated by the light of a flash bulb energized through the shutter switch mechanism of the camera. Its purpose is to avoid the complications and inconvenience encountered where lengthy extension wires are used to synchronize auxiliary flash bulbs with the firing of the bulb at the camera. Mr. Deck built such an electric device as part of his thesis preparation.

It was the first time St. Louis University competed in the contest, which included participants from Missouri University, Rolla School of Mines, and Washington University. Mr. Deck received an award of $20 and the school a silver cup, which if won three times by the same school becomes a permanent possession.

AIEE-ASME Joint Meeting Held by Erie Sections

The Erie Sections of the AIEE and The American Society of Mechanical Engineers held a joint meeting in Erie, Pa., on June 24, 1949, which began at 8:30 a.m. and lasted all day. The subject of the meeting was the first gas turbine-electric locomotive built in America.

Members of the surrounding sections of both societies and national officers of both societies were invited to attend the joint meeting, and those attending spent the day in discussion of papers on the technical aspects of the locomotive and in riding and inspecting the locomotive. Technical papers were prepared by A. H. Morey, ASME; O. C. Coho, AIEE; T. J. Warrick, AIEE; and A. O. Howard, ASME.

Nashville Subsection Completes Organization

The Nashville Subsection of the AIEE Memphis Section completed its organization at a meeting on Thursday night, May 19, 1949. Bylaws to govern the organization of the Subsection were adopted and the following officers for the coming year were elected: Walter Criley of the Electrical Engineering Department of Vanderbilt University, Chairman; and E. R. Boruch, Nashville District Manager of the BullDog Electric Products Company, Secretary-Treasurer.

The May meeting was the final meeting before the summer months. The first meeting of the fall season will be held early in October.

Manhattan College Senior Wins Second Prize in AIEE Contest

Second prize in the AIEE Prize Papers Contest covering colleges of the metropolitan area has been awarded to Peter V. Martino, senior electrical engineering student at Manhattan College, Riverdale, N. Y., for his work and paper on the "Hilsch Tube" involving improvements in refrigeration processes. Mr. Martino's technical paper first appeared in the March issue of the *Manhattan Engineer*. The contest included entries from ten colleges and the awards were made on the basis of written and oral presentations.

Brother Amandus Leo, F.S.C., Dean of Engineering at Manhattan College, in congratulating Mr. Martino on his achievement, pointed out that last year's AIEE award also had been won by a Manhattan College engineering student, John B. Walsh, who won first prize for his paper on "Nonlinear Functions," a mathematical analysis of a problem peculiar to magnetic circuits.

COMMITTEE NOTES •

Editor's Note: This department has been created for the convenience of the various AIEE technical committees. It will include brief news reports of committee activities and proposed plans for such projects as special technical conferences and sessions at general meetings. Items *for this department, which should be as short as possible, should be forwarded to R. S. Gardner at AIEE Headquarters, 33 West 39th Street, New York 18, N. Y.*

Power Group

Joint Subcommittee on Application of Probability Methods to Capacity Problems. (*G. Calabrese, Chairman; V. A. Thiemann, Secretary*). The subcommittee was organized in the summer of 1948 under the auspices of the Power Generation Committee and the System Engineering Committee for the purpose of studying the application of probability methods to reserve problems. Since then, the subcommittee has considered the following projects: publication of steam units and hydro units outage data collected under the auspices of the Edison Electric Institute; bibliography; terminology; survey of methods of load scheduling and practice of spinning reserve; development of short-cut methods of determining reserve by the probability method; application of the probability method to the effect of load forecasting on reserve determination; application of the probability method to the allocation of reserve savings resulting from interconnections; reactive kilovolt-amperes reserve requirements; application of the probability method to the determination of feeder and transformer reserve requirements.

A report on outage rates was presented at the January 1949 Winter General Meeting of the AIEE. The bibliography also has been completed and will be published together with the report on outage rates.

The objective of the project on terminology is the co-ordination of the terms now used in connection with reserve problems and the recommendation of new terms as made necessary by the recent application of the probability theory to reserve problems.

What methods of load scheduling are used at present by the various companies? What methods are used in determining spinning reserve? Can the probability theory be applied to load scheduling and spinning reserve problems? These are the questions which prompted the "survey of methods of load scheduling and practice of spinning reserve."

The objectives of the other projects are self-explanatory and need no additional comment.

It should be emphasized that the degree of completion of the various items, particularly the terminology and the survey of load scheduling and practice of spinning reserve, depends upon the response and co-operation of the companies which are to supply the necessary data to the subcommittee.

Committee on Protective Devices. (*G. B. Dodds, Chairman; W. J. Rudge, Vice-Chairman; E. G. Norell, Secretary*). The work of this committee is concerned with matters relating to limitation or prevention of damage to electric equipment or systems where such damage may arise from excessive current voltage, or lightning. The active projects include those discussed in the following paragraphs.

Four application guides are being prepared. One will deal with different methods of grounding synchronous generator systems and will discuss such methods as potential transformer, distribution transformer, resistance, reactance, and direct grounding. A companion guide will apply to methods of grounding transmission systems of 22 kv and above. It will discuss the application of grounding transformers, grounding reactors and resistors, and ground fault neutralizers. Also, the limitation of ground fault current and transient overvoltages, ground relaying, and arrestor protection. Both of these guides will discuss the basic factors and considerations in system grounding and will summarize briefly those methods which are considered to be best practice. A third guide on grounding will deal with the application of ground fault neutralizers. This will review the voltage, current, frequency, and time ratings of these devices and will give application criteria dealing with insulation levels, number and location of units on a system, system interconnection, and so forth. The fourth guide will deal with the selection and application of lightning protective devices for the protection of equipment in substations. Factors taken into consideration will include system operating conditions, grounding conditions, distance of protective devices from protected apparatus. The first three of these guides will be presented at the Fall General Meeting at Cincinnati, Ohio.

Other projects include bibliography of literature on grounding devices; field survey of unbalanced charging currents of ground fault neutralizer installations; power system fault limitation, a study to determine ways and means of limiting short-circuit kilovolt-amperes to reasonable values; revision and combination of AIEE Standards 24 (protective tubes), 28 (lightning arrestors for a-c power circuits), and 47 (expulsion-type distribution lightning arrestors); performance characteristics of lightning protective devices, which is a report which will combine in one place the important characteristics of the various types of lightning protective devices available; and recovery voltage characteristics of distribution systems.

This last item is joint with the General System Subcommittee of the Transmission and Distribution Committee. The purpose of this last project is to set up duty cycle test specifications for incorporation in lightning arrestor Standards dealing with expulsion arrestors.

Committee on Rotating Machinery. (*C. E. Kilbourne, Chairman; W. R. Hough, Vice-Chairman; R. V. Shepherd, Secretary*). A total of 48 papers sponsored by this committee were presented at the AIEE meetings during the past year; of these 29 were presented at the Winter General Meeting. Activities of the various subcommittees include the following.

Report 43A, "Recommended Practices for Insulating Testing of Rotating Machinery," has been submitted and after final agreement it will be published as an AIEE Standard. The formulation of a test code for fractional-horsepower motors is under way and an application guide for fractional-horsepower motors is contemplated. A test code for induction machines is nearly completed and is expected to be submitted for approval in the near future.

The results of a 3-year test program of measurement of temperature rises of small d-c machines has indicated that a change in the Standards for temperature rise measurement is necessary. Additional data are being obtained on large d-c equipment, as results obtained on large machines differ from those on small machines. The investigation of a standard method of determining short-circuit current on d-c machines is under way.

The compilation of a bibliography on rotating machinery is being made, and when completed it is expected that this report will be published.

Industry Group

Committee on Electric Welding. (*E. H. Vedder, Chairman; Myron Zucker, Vice-Chairman; C. N. Clark, Secretary*). The Electric Welding Committee sponsored a session at the Summer General Meeting at Swampscott; a conference session devoted to both arc and resistance welding subjects. The Subcommittee on Power Supplies for Resistance Welding also is continuing its efforts to revise the existing publication by a previous subcommittee on this subject. The material is being modernized to include mostly up-to-date information regarding the provision of power for resistance welding apparatus. The committee already has started preparing for the 1950 Conference on Electric Welding to be held in Detroit. Myron Zucker, Vice-Chairman of the Electric Welding Committee, is heading the preparations for the next conference and is making a special effort completely to co-ordinate with the American Welding Society and the Industrial Engineers Society of Detroit.

Subcommittee on Induction and Dielectric Heating. (*W. C. Rudd, Chairman; J. E. Eiselein, Secretary*). This committee has changed its name from Subcommittee on Electronic Heating to Subcommittee on Induction and Dielectric Heating since it is believed that the latter name is more descriptive of its function. The subcommittee is part of the Electric Heating Committee and has completed a proposed Standard on "Good Engineering Practice in Cases of Radio Interference." It is hoped that this proposed Standard will help users of induction and dielectric heating equipment to correct the operation of their equipment where it interferes with radio communications. The group now is engaged in two projects, one of which is the writing of a standard set of definitions for the industry, and the other the setting up of a Standard on equipment, its operation, and test.

Communication and Science Group

Committee on Electronics. (*C. H. Willis, Chairman; W. G. Dow, Vice-Chairman; T. P. Kinn, Secretary*). The Electronics Committee attempts to bring to the attention of the AIEE new techniques and engineering practices employing electronic devices. This policy is pursued in co-operation with other committees wherever possible. In some instances the Electronics Committee forms technical subcommittees to further these objectives. In addition to the several liaison committees, there are technical subcommittees on Electron Tubes, X-Ray Tubes and Apparatus, Electronic Precipitation, High-Frequency Conductors and Cables, Electronic Aids to Medicine, Electronic Aids to Geophysics, Magnetic Amplifiers, Electronic Applications of Semiconductors, and Industrial Applications of Spectroscopy. There is also a Joint Committee on Electronic Instruments.

Acting through its numerous subcommittees, the Electronics Committee has participated during the past year in two conferences and five technical sessions for general meetings of the Institute with two additional technical sessions at the Summer General Meeting at Swampscott, Mass. The conference on "Electronic Instrumentation for Nucleonics and Medicine," which was sponsored jointly by the AIEE and the Institute of Radio Engineers, was held in New York on November 29–December 1. The success of this conference was so outstanding that a second meeting is being planned by the Committee on Electronic Aids to Medicine in co-operation with the other interested groups.

The conference on "Industrial Applications of Electron Tubes," held in Buffalo, N. Y., on April 11 and 12, was one of the highlights of the year's technical activities. This meeting which was organized by the Electron Tube Subcommittee and the Industrial Control Committee presented a very interesting program and was attended by 229 representatives of manufacturers and industrial users of electron tubes.

At the Winter General Meeting in New York City in January 1949, the Electronics Committee sponsored a technical session dealing with recent developments in electron tubes and circuits, the usual conference session on new electronic devices, a technical session on high-frequency cables, a conference session on education in power electronics, and a technical session on electrostatic precipitation. For the Summer General Meeting in Swampscott the appropriate subcommittees sponsored a technical session on infrared applications, another on magnetic amplifiers, and co-operated in the symposium on semiconductors organized by the Basic Sciences Committee.

One of the basic policies of operation in this committee is to encourage the presentation, in sessions sponsored by other committees of the Institute, of papers having an important electronic content. As a result of the interest and co-operation of these technical committees, approximately half of all the papers presented at the Winter General Meeting referred to some phase of electronics as an essential feature of treatment in the paper.

Committee on Electronic Power Converter. (*H. Winograd, Chairman; C. C. Herskind, Vice-Chairman; H. C. Steiner, Secretary*). During the last decade there were many new developments in designs and applications of mercury-arc power converters; there was also a large increase in the number of rectifier installations and the total installed kilowatt capacity. To assist the application and operating engineers, the committee activities have been concentrated on the preparation of technical and educational material relating to the application of rectifiers.

The Standards for pool-cathode mercury-arc power converters, prepared by the committee in 1946, will be issued soon as ASA Standard C34.1-1949.

A report, "Mercury-Arc Power Converters in North America" (AIEE *Transactions*, volume 67, 1948, page 626), summarized the American design and application practices.

The committee has been working on the following projects, which will be completed this year: bibliography for electronic power converters, from 1903 to 1947; report on protection of electronic power converters, which deals with protection practices and the calculation of fault currents; report on the characteristics of rectifier transformers; report on inductive co-ordination relating to the d-c side of rectifier installations. This will complement the report "Inductive Co-ordination Aspects of Rectifier Installations" (AIEE *Transactions*, volume 65 July 1946, pages 417–36) which dealt with the a-c side; and survey of operation of mercury-arc rectifiers, by means of questionnaires sent to rectifier users.

The following projects have been proposed for future committee action: report on cooling systems for mercury-arc rectifiers; standardization of nomenclature and definitions for electronic motor drives, jointly with other interested committees; determination of equivalent circuit characteristics of a rectifier installation, for d-c power system studies; assistance to educators in power electronics.

AIEE PERSONALITIES.....

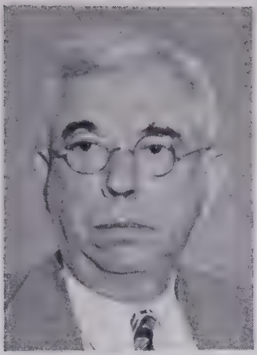
Harold Pender (A '06, F '14), retires July 1 as dean, Moore School of Electrical Engineering, University of Pennsylvania, Philadelphia, after 26 years in the post. He will continue his association with the institution as a consultant. Dr. Pender received a bachelor of arts degree in 1898 and a doctor of philosophy degree in 1901, both from the Johns Hopkins University. After two years of teaching, he went to La Sorbonne, Paris, France, in 1903, and did work proving that a magnetic field exists around a moving electrically charged body. Returning to the United States, he worked as an electrical engineer for several industrial concerns, and in 1909, joined the faculty of the Massachusetts Institute of Technology, Cambridge, Mass., as professor of electrical engineering. In 1914, he was appointed director of electrical engineering at the University of Pennsylvania, and nine years later, was named dean of the Moore School. In 1924, the university granted him the honorary degree of doctor of science. The author of four books and numerous articles on electrical engineering, Dr. Pender is a member of the International Electrotechnical Committee, American Philosophical Society, the Franklin Institute, and the American Academy of Arts and Sciences. He is a Member-for-Life.

C. C. Chambers (A '35, M '44), professor of electrical engineering, has been appointed dean of the University of Pennsylvania's Moore School of Electrical Engineering, Philadelphia, for a one-year term. He replaces Harold Pender, who is slated to retire. A 1929 graduate of Dickinson College, he subsequently was employed by the Radio Corporation of America, working on the development of vacuum-tube test equipment and circuit analysis. In 1932, he resigned to become a special fellow at the Bartol Research Foundation, and one year later was named an instructor of electrical engineering at the Moore School. Receiving a doctor of science degree in 1934, he became an assistant professor in 1938, an associate professor four years later, and professor in 1947. During World War I, he was technical consultant for most of the war research contracts at the Moore School. Holder of patents on vacuum-tube measurement, electronic control, and photographic processing, Dr. Chambers is a member of the Institute of Radio Engineers, the American Physical Society, the American Society for Engineering Education, and the Franklin Institute.

Ward Harrison (F '36), who until recently was director of engineering of the General Electric Company's lamp department, Cleveland, Ohio, has been awarded the 1949 IES Gold Metal by the Illuminating Engineering Society "for meritorious achievement conspicuously furthering the profession, art, and knowledge of illuminating engineering." The official presentation will take place at the IES meeting to be held at French Lick, Ind., during the week of September 19, 1949. Now an engineering consultant for Curtis Lighting, Inc., Chicago, Ill., Dr. Harrison is noted for having designed the RLM Standard reflector, the glassteel diffuser, the first clear-top enclosed semi-direct luminaire, and the first street lighting fixture with a prismatic dome reflector. He received a degree in mechanical engineering from the Stevens Institute of Technology in 1909, and in the year of his graduation, joined General Electric. President of the IES, 1922–23, Dr. Harrison was awarded the honorary degree of doctor of illuminating engineering from the Case School of Applied Science in 1940, the first such degree granted in America.

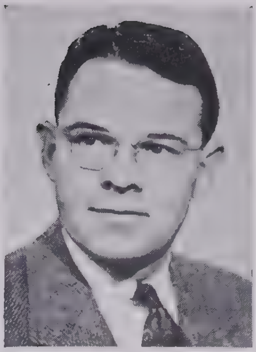
M. L. Waring, (A '29, M '36), planning engineer of Consolidated Edison Company of New York, Inc., New York, N. Y., since 1947, has been elected an assistant vice-president. He assists J. F. Fairman, (A'20, F'35) vice-president in charge of electric and gas production and operation. In 1933, Mr. Waring joined the New York Edison Company, a predecessor of Consolidated Edison, as a junior engineer. In 1936, he was made an assistant engineer. He served with the Army Ordnance Department in World War II. In 1944 he saw action in the China theater of operations with the Z-Force, a group responsible for training Chinese troops and accompanying them into battle. Later, Mr. Waring became ordnance officer of the China theater. At the end of the war he

M. L. Waring



C. W. Mayott

M. W. Smith



W. D. Kyle, Jr.

held the rank of lieutenant colonel. He was awarded the Legion of Merit for his services. Returning to Consolidated Edison, Mr. Waring spent a year on the company's executive development program. Since 1947 he has been responsible for planning the development of the system's electric, gas, and steam properties. Born in Chicago, Ill., June 14, 1906, he received a degree in electrical engineering from the Virginia Military Institute in 1927. After his graduation, he entered the test course of the General Electric Company in Schenectady, N. Y., and remained with that firm until 1932 as a member of the central station engineering department. In 1932, Mr. Waring completed postgraduate work at Union College and received a master of science degree in electrical engineering. A member of the System Engineering Committee, he is serving on the New York Engineer's Committee on Student Guidance.

C. W. Mayott (A '13, M '43), assistant to the president, Hartford (Conn.) Electric Light Company, is in Europe during the early-summer months on assignment of the United States Government. His job is assisting the Economic Co-operation Administration in a survey of France's power resources. He has been granted a leave of absence by the Hartford utility. Manager of the Connecticut Valley Power Exchange, 1925–45, he was lent to the government in 1941 to act as co-ordinator of 40 interconnected private and public power systems in 13 Southeastern states to avert threatened shortages of energy. Later, he became Deputy Chief of Power Supply for the Office of War Utilities, War Production Board, pooling power on a nationwide basis. In 1947, he was named consultant for the Industrial College of the Armed Forces. A native of Cohoes, N. Y., born January 30, 1887, Mr. Mayott was graduated from Rensselaer Polytechnic Institute in 1911. He joined the Hartford Electric Light Company in the same year, and subsequently held the positions of assistant superintendent of power and mechanical engineer. Mr. Mayott is chairman of the Electrical Interconnections Task Group of the United States National Securities Resources Board. He served on the Power Generation Committee, 1940–47, and the System Engineering Committee, 1947–49.

M. W. Smith (A '20, F '42), formerly executive vice-president, the Baldwin Locomotive Works, Philadelphia, Pa., has been elected president and chief executive officer of the company. Mr. Smith came to Baldwin in 1948 from the Westinghouse Electric Corporation where he had been vice-president in charge of engineering and research. He had joined that firm shortly after his graduation from the Agricultural and Mechanical College of Texas in 1915. Following completion of the graduate student course in 1917, he was appointed design engineer in the power engineering department, and promoted to section engineer ten years later. Appointed division engineer in 1930, he was put in charge of the designing of many large generators, such as those for Hoover and Norris Dams. Under his direction, Westinghouse developed the "umbrella" type of construction for large water wheel generators, used in low-speed hydro-power stations. In 1936, he advanced to manager of engineering, and he became vice-president in 1939. A native of Overton, Tex., born October 8, 1893, Mr. Smith holds several patents pertaining to rotating machinery. He is a member of the American Association for the Advancement of Science and American Society of Mechanical Engineers.

W. D. Kyle, Jr. (A '37, M '44), formerly executive vice-president of the Line Material Company, Milwaukee, Wis., has been elected president of the firm. An electrical engineering graduate of Cornell University, class of 1936, Mr. Kyle's first industrial experience was with the Wisconsin Electric Power Company. In 1937, he joined the Line Material Company as an industrial engineer, working on the development of new processes and methods of production. Later, he transferred to the research department. In 1939, he became associated with the Kyle Corporation (formerly the Electrical Connectors and Manufacturing Company) as chief engineer. Subsequently, he advanced to vice-president and then to president, in 1941. When the Kyle Corporation was merged with Line Material in 1947, he became executive vice-president. Mr. Kyle is a native of Milwaukee, and was born May 18, 1915.

C. A. Powel (M '20, F '41), assistant to the vice-president in charge of engineering, Westinghouse Electric Corporation, East Pittsburgh, Pa., has been named lecturer in electrical engineering, the Massachusetts Institute of Technology, Cambridge. His duties will begin in the fall of 1949. He will teach advanced courses in the use of electric power by heavy industry. Born in France, Mr. Powel was educated in England and in Switzerland. During the early part of his career, he worked for the Swiss firm of Brown Boveri and Company, and after serving in the British army in World War I, he joined Westinghouse in 1919. On leave of absence from the company in 1946, he served as a section chief with the Allied Control Commission in Berlin, and helped to establish control of the German electrical and radio manufacturing industries. In 1948, he served as power consultant to the Stillman Mission, which surveyed industries of China for the Economic Co-operation Administration. An active Institute member, Mr. Powel was President, 1944–45, Vice-President (District 2) 1942–43, Director, 1936–40. Some of the committees on which he has served are: Power Generation; Electric Welding; Electrochemistry and Electrometallurgy; Executive; Lamme Medal; Standards; and Education.

H. B. Reynolds (M '41, F '47), superintendent, power generation, New York City (N. Y.) Transit System, has retired to become associated with the J. G. White Engineering Corporation. With the transit system and its predecessor, the Interborough Rapid Transit Company, for 35 years, Mr. Reynolds served successively as assistant engineer, mechanical research engineer, mechanical engineer, superintendent of motive power of the Interborough Rapid Transit Division, and finally superintendent of power generation for the entire system. He was a member of the Power Generation Committee, 1943–46.

P. J. Carlin (A '36, M '37), formerly superintendent of distribution, Florida Power and Light Company, Miami, has joined the Southeastern Utilities Service Company as vice-president. The firm's headquarters are in Miami. Mr. Carlin has been identified with Miami utility properties for 28 years. He became associated with the Miami Electric Light and Power Company in 1914, and held positions successively of betterment engineer, chief load dispatcher, and superintendent of distribution.

W. F. McMullen (A '45) has been appointed manager of the technical personnel division of the Canadian General Electric Company, Toronto, Ontario. One of his principal duties will be the recruiting of engineering graduates for the company's test course, and assisting in their final placement within Canadian General Electric or industry generally. Mr. McMullen was on the staff of the University of Toronto before joining the company, and for a period during 1947, he did work for the Canadian Electrical Manufacturers Association.

W. J. Gilson (A '26, M '38), president of Eastern Power Devices Limited, Toronto, Ontario, Canada, has been made a director of I-T-E Circuit Breaker Company, Philadelphia, Pa. This appointment follows an amalgamation of interests between the two companies. An active AIEE member, Mr. Gilson was Vice-President of District 10, 1943–45, and served on the following committees: Membership; Edison Medal; Electrochemistry and Electrometallurgy; Sections; and Switchgear.

H. L. Eicher (A '25) is senior member of Eicher and Company, Seattle, Wash., which firm recently took over the engineering, sales, and servicing operations of Esterline-Angus recording instruments and associated products in the Seattle territory. Mr. Eicher organized the firm of Eicher and Bratt, manufacturers' representatives, in 1919, and in 1947, this organization became Eicher and Company.

Howard Reeve (A '25, M '41) has been appointed manager of the Des Moines district of the Iowa Power and Light Company. Identified with the utility for more than 25 years, Mr. Reeve formerly was superintendent of electric distribution. Other promotions in the company are **Jack Sayre** (A '47) to manager of outside districts and **J. L. Culhane** (A '46) to engineer in charge of transmission and distribution.

M. H. McGrath (A '26), formerly assistant chief engineer, has been appointed chief engineer, product engineering, the General Cable Corporation, Bayonne, N. J.

OBITUARY • • • • • •

Fred A. Rogers (A '06, M '28) dean emeritus of the Illinois Institute of Technology, Chicago, Ill., died March 18, 1949. Born September 26, 1869, in Kent County, Mich., he received an engineering degree from the University of Michigan in 1894. Following graduation, he worked for the Vermillion (S. Dak.) Milling and Electric Company. In 1896, he joined the staff of the Lewis Institute of Technology, Chicago, Ill., as an instructor in physics and electrical engineering. Six years later, he was advanced to assistant professor, and in 1909, he became professor. Named head of the physics and electrical engineering departments in 1918, he became dean of engineering in 1932. After 45 years service, he retired from the faculty in 1941, but when Lewis Institute was merged with the Illinois Institute, he returned to head the latter's war training program, and at the end of the war retired as dean emeritus. Besides teaching, Mr. Rogers had been engaged in consulting and testing work since 1900. He was a member of the American Association for the Advancement of Science, the Illuminating Engineering Society, and the Western Society of Engineers. A Member-for-Life, Mr. Rogers served on the Production and Application of Light Committee, 1926–29, 1937–38, and the Electrophysics Committee, 1936–37.

Walter Walker Stubbs (A '26, M '41) of the Acme Electric Corporation, Cuba, N. Y., died April 12, 1949. A native of Middletown, Ohio, born December 10, 1900, Mr. Stubbs had been associated with Acme since 1941. Previously, he had been with the Davis Transformer Company, Concord, N. H., for ten years, doing design and testing work. During the early part of his career, he had been an electrician, and from 1928–30, he was with the Ford Motor Company, Hamilton, Ohio. At Acme, he had been plant manager of the air cool division and manager of the dry-type-transformer division, successively.

Henry Harrison Wotherspoon (A '28, M '45), field engineer, Mathias Klein and Sons, Chicago, Ill., died April 5, 1949. A native of New York, N. Y., born October 19, 1872, he was an alumnus of Columbia University. Joining the Edison Illuminating Company, New York, N. Y., in 1894, he later worked successively for the Mexican National Railway, the Transcontinental Railway of Canada, and the South American Development Company at their Ecuadorian mines. Becoming associated with Mathias Klein in 1925, some of his subsequent accomplishments were the invention of a special safety belt for line workers, the development of a wire rope grip used by the United States Navy in towing operations connected with mine sweeping, and the development of climbing devices for the Signal Corps.

Frederick Cecil Finkle (A '08), consulting hydraulic engineer and geologist, Beverly Hills, Calif., died April 7, 1949. A native of Viroqua, Wis., he was born May 3, 1865. After his graduation in 1886, he went to California where he did engineering work in water supply and power for the next dozen years. During the interval 1898–1907, he was employed by the Southern California Edison Company and its predecessor utilities. While there, he assisted in the design and construction of seven hydroelectric plants. A consulting engineer for the rest of his career, Mr. Finkle was noted for having been a chief engineer on the first hydroelectric 3-phase power plant constructed in the United States. Because of his reputation as a water expert, he was called upon in three important litigations. In one case involving the San Diego Company, he was on the witness stand for 121 days, the world's record for expert testimony. He worked on behalf of the Los Angeles Flood Control District in the "San Gabriel River Forks Dam" case, and was consulting engineer for the cities of Burbank and Glendale in their water rights fight against the city of Los Angeles. The author of many technical papers, he was a member of the American Association of Engineers, the American Water Works Association, and The American Society of Mechanical Engineers. He was a Member-for-Life of the AIEE.

Edwin Henry Kifer (A '09, F '45), manager of the San Antonio (Tex.) City Public Service Board, died April 14, 1949. Before the city acquired the utility properties, he was vice-president and general manager of the San Antonio Public Service Company. Mr. Kifer acquired his first utility experience with the Madison (Wis.) Gas and Electric Company. There from 1904–16, he worked in various engineering capacities, including superintendent of the electrical department and general superintendent. After two years with the Binghamton (N. Y.) Gas Company, he joined the San Antonio Public Service Company, remaining there until 1931. During the next dozen years he was president, general manager, and director of the Muskegon (Mich.) Gas Company, president of the Texas Gas Distributing Company, San Antonio, and business manager of the San Antonio Board of Education. He assumed his last position, that of manager of the City Public Service Board, in 1943. A native of Lincoln, Nebr., born June 8, 1884, he received his electrical engineering degree from the University of Wisconsin in 1908. Mr. Kifer was a Member-for-Life.

John Smith Ware (M '21, F '44), general superintendent of electric distribution, Public Service Corporation of New Jersey, Newark, died April 23, 1949. Immediately after graduation from the Stevens Institute of Technology in 1910, he became associated with the Public Service Corporation as a record clerk in the electric distribution department. In 1916, he was designated distribution engineer, and eight years later was named assistant general superintendent of distribution. In 1930, he advanced to superintendent. A native of Mauricetown, N. J., born August 2, 1886, he was active in the Edison Electric Institute, the American Standards Association, and the American Wood Preservers' Association. A member of Tau Beta Pi, he also belonged to the old National Electric Light Association.

Norman J. Goutink (A '28), electrical designer, mechanical engineering department, the Kellex Corporation, New York, N. Y., died March 21, 1949. A native New Yorker, born July 14, 1903, he worked from 1920 to 1925 for Thomas E. Murray, Inc. During the next three years, he was employed by the Holland Tunnel Commission, doing design, testing, and inspection work. In 1928, he joined the D. P. Robinson Company. Subsequently, he became associated with the old United Electric Light and Power Company and the New York City Tunnel Authority. He joined the Kellex Corporation four years ago.

Addison Wolcott Lee, Jr. (A '08, M '40), vice-president in charge of operations, Louisville (Ky.) Gas and Electric Company, died May 1, 1949. A 1906 graduate of Rose

Polytechnic Institute, he worked one year for the Chicago and Eastern Illinois Railroad before joining the Louisville Lighting Company as construction inspector, the supervision of the the construction of the first a-c substation in Louisville being one of his tasks. After serving four years as chief of drafting and inspection with the Louisville Gas and Electric Company (successor to Louisville Lighting), he became assistant general superintendent in 1917, and general superintendent in 1926. He was named to his last position in 1932. The author of several engineering articles, Mr. Lee was born July 31, 1885, in Louisville. He was a Member-for-Life.

Farrell Meredith Scarlett (A '47), manager, Packard Electric Company, Montreal, Quebec, Canada, died May 6, 1949. Born in Ridgetown, Ontario, Canada, in 1888, he was employed during the early part of his career by the Corporation of the City of Edmonton (Alberta) and the Northwest Electric Company, Calgary, Alberta. After several years with the Canadian General Electric Company, he joined the Packard Electric Company in 1923, and continued there until the time of his death.

Walter Eugene Smith (A '00), inspector of Navy material, Bureau of Engineering, United States Navy, Washington, D. C., died April 21, 1949. He was born in Newark, N. J., on January 4, 1875. Leaving college in 1894, he subsequently did laboratory work related to electric-lamp filaments, and later was employed as a machine-shop draftsman. Until 1914, he was an electrician working for the United States Navy in Philadelphia, Pa. He was an inspector for the Navy in 1916, and an inspecting engineer one year later. During the next two decades, his designation was assistant inspector of engineering material. In 1937, he was advanced to the position which he held at the time of his death. He was a Member-for-Life.

MEMBERSHIP • •

Recommended for Transfer

The board of examiners at its meeting of May 19, 1949, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the secretary of the Institute. A statement of valid reasons for such objections must be furnished and will be treated as confidential.

To Grade of Fellow

Bohn, D. I., chief elec. engr. Aluminum Co. of America, Pittsburgh, Pa.
Brower, R. F., system engr., Consolidated Edison Co. of N. Y., Inc., New York, N. Y.
Garin, A. N., section engr., General Electric Co., Pittsfield, Mass.
Garrett, P. B., editor, *Electric Light and Power*, Chicago, Ill.
Hart, L. C., pres., Hi-Voltage Equipment Co., Cleveland, Ohio.
Janes, L. R., development engr., Public Service Co. of Northern Illinois, Chicago, Ill.
Milne, G. R., mechanical engr., Consolidated Edison Co. of N. Y., Inc., New York, N. Y.
Muller, H. N., Jr., mgr., educational dept., Westinghouse Electric Corp., East Pittsburgh, Pa.
Pearce, Cullen Thomas, Middle Atlantic engg. & service mgr., Westinghouse Electric Corp., Phila., Pa.
Smith, W. C., special studies engr., Michigan Bell Telephone Co., Detroit, Mich.
Stringham, L. K., chief application engr., Lincoln Electric Co., Cleveland, Ohio
Thomas, E. R., test engr., Consolidated Edison Co. of N. Y., Inc., New York, N. Y.
Warrington, A. R. V., supervisor, relay engg. section, General Electric Co., Phila., Pa.

13 to grade of Fellow

To Grade of Member

Anderson, B. H., treas., Marcus Transformer Co., Inc., Hillside, N. J.
Baldwin, C. H., senior elec. engr., Ford, Bacon & Davis, Inc., Chicago, Ill.
Balwanz, W. W., elec. engr., Naval Research Lab., Washington, D. C.
Bartholomee, T. M., general foreman, Consolidated Gas Electric Light & Power Co., of Baltimore, Md.
Beall, B. S., III, designing engr., air circuit breaker div., General Electric Co., Phila., Pa.
Bos, J.. elec. engr., The Austin Co., Cleveland, Ohio
Burns, C. H., section engr., Westinghouse Electric Corp., Cleveland, Ohio
Clark, J. A., elec. design engr., Reliance Electric & Engg. Co., Cleveland, Ohio
Cline, T. H., elec. engr., Newark Stove Co., Newark, Ohio
Cortelli, J. A., chief engr., Clark Controller Co., Cleveland, Ohio
Davidson, D. R., senior engr., Cleveland Electric Illuminating Co., Cleveland, Ohio
Davis, D. H., supt. production & transmission, South Carolina Power Co., Charleston, S. C.
Callaher, B. M., elec. engr., Ebasco Services, Inc., New York, N. Y.
Geiger, L. J., Jr., sales engr., General Electric Co., Schenectady, N. Y.
Gentilini, C., asst. chief engr., National Electric Coil Co., Columbus, Ohio
Gorman, R. E., elec. engr., generator engg. div., General Electric Co., Schenectady, N. Y.
Goudy, P. R., development engr., ind. con. div., Square D Co., Milwaukee, Wis.
Graham, R. S., member technical staff, Bell Telephone Labs., Murray Hill, N. J.
Graves, D. E., design engr., General Electric X-Ray Corp., Milwaukee, Wis.
Green, W. M., elec. engr., Bureau of Reclamation, Fresno, Calif.
Hamm, C. L., motor design engg., General Electric Co., Lynn, Mass.
Harbage, B., asst. to chief engr., The Jeffrey Mfg. Co., Columbus, Ohio
Headley, C. L., supervisor, elec. system protection div., Consolidated Gas Electric Light & Power Co., of Baltimore, Md.
Holley, C. H., requisition section, turbine generator engg., General Electric Co., Schenectady, N. Y.
Horney, H. W., elec. engr., B. O. Vannort Engineers, Inc., Charlotte, N. C.
Huff, J. F., div. maintenance supervisor, Southwestern Bell Telephone Co., Wichita, Kans.
Hutchison, D. P., exchange engr., Southwestern Bell Telephone Co., Wichita, Kans.
Jedrziewski, A. A., asst. div. engr., West Penn Power Co., Ridgway, Pa.
King, D., system operating engr., Shawinigan Water & Power Co., Shawinigan Falls, Quebec, Canada
Laudenslager, R. L., asst. prof., elec. engg., University of Connecticut, Storrs, Conn.
London, J. B., vice-pres. & treas., Purser & London, Inc., Charlotte, N. C.
Mann, P., asst. prof. of elec. engg., University of Idaho, Moscow, Idaho
Martin, B. V., sales engr., Westinghouse Electric Corp., Charlotte, N. C.
McCleece, H. M., design engr., Curtiss-Wright Corp., Columbus, Ohio
Messerschmidt, H. L., manufacturing elec. engr., Western Electric Co., Chicago, Ill.
Millican, H. G., genl. supt. & elec. engr., O. V. Scott Elec. Co., Atlanta, Ga.
Morgan, R. E., development engr., General Electric Co., Schenectady, N. Y.
Moulthrop, R. A., technical assistant, Pacific Gas & Elec. Co., Oakland, Calif.
O'Conor, J. J., asst. to supt., electric test dept., Consolidated Gas Electric Light & Power Co. of Baltimore, Md.
Parker, F. T., transportation control engg., General Electric Co., Erie, Pa.
Perkins, K. H., electronics engr., Anchor Hocking Glass Corp., Lancaster, Ohio
Rogers, E., staff engr., Public Service Co. of Northern Illinois, Chicago, Ill.
Rosswog, J. G., elec. engr., Reliance Electric & Engineering Co., Cleveland, Ohio
Skillen, J. P., division engr., switchgear div., Canadian Westinghouse Co., Ltd., Hamilton, Ontario, Canada
Steele, R. B., chief engr., Canadian National Telegraphs, Toronto, Ontario, Canada
Stirling, L. B., asst. genl. supt., generation & transmission dept., Shawinigan Water & Power Co., Shawinigan Falls, Quebec, Canada
Stringer, G. L., elec. engr., Bureau of Reclamation, Denver Federal Center, Denver, Colo.
Sunkel, R. F., elec. engr., Shell Oil Co., Inc., Wood River, Ill.
Swafford, J. D., elec. engr., Black & Veatch, C. E., Kansas City, Mo.
Thompson, W. F., manufacturers' representatives, Control Corp., Denver, Colo.
Trice, T. W., asst. genl. supt., electric operations, Consolidated Gas Electric Light & Power Co., of Baltimore, Md.
Waynick, A. H., professor, elec. engg., The Pennsylvania State College, State College, Pa.
Webb, H. C., vice pres., Puget Sound Power & Light Co., Seattle, Wash.
Witte, W. J., asst. supt., electric distribution, Consolidated Gas Electric Light & Power Co., of Baltimore, Md.
Yanda, G. J., asst. to genl. supt. of services, The Cleveland Illuminating Co., Cleveland, Ohio

55 to grade of Member

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. Any member objecting to the election of any of these candidates should so inform the secretary before July 21, 1949, or September 21, 1949, if the applicant resides outside of the United States, Canada, or Mexico.

To Grade of Member

Allcorn, W. M., The H. K. Ferguson Co., Cleveland, Ohio
Anderson, C. M., Lansdale Municipal Power Plant, Lansdale, Pa.
Chamberlin, E. C., Jr., Western Union Tel. Co., New York, N. Y.
Courtenay, J. A., Southern Bell Tel. & Tel. Co., Jackson, Miss.
Dawson, J. A., Rocky Mt. College, Billings, Mont.
Dennis, F. L., Boston Edison Co., Boston, Mass.
Dunkelberger, W., Isis Theatre, Fargo, N. Dak.
Fackler, R. W., Indiana & Michigan Elec. Co., Ft Wayne, Ind.
Gable, A. C., General Elec. Co., Schenectady, N. Y.
Gindele, D. F., REA-USDA, Washington, D. C.
Gompf, A. M., Egli & Gompf Co., Baltimore, Md.
Hatch, M. M. (Miss), AIEE, New York, N. Y.
Hartle, M. W., Lonas Elec. Co., Knoxville, Tenn.
Hartley, B. H., 9621 Arroya Vista Drive, Phoenix, Ariz.
Jaworski, Z. J., Hydro Elec. Power Com. of Ontario, Toronto, Ontario, Canada
Johnson, P. L., New York Tel. Co., Brooklyn, N. Y.
Keaton, L., Western Elec. Co., Inc., Kearny, N. J.
Kempton, F. M., Prince Rupert Municipal Tel. Systen, Prince Rupert, British Columbia, Canada
Kline, H. W., General Elec. Co., Schenectady, N. Y.
Langford, A. D., Kentucky Utilities Co., Lexington, Ky.
Lee, B. C., Ministry of Education, London, England
Lippincott, W. F., E. I. du Pont de Nemours & Co., Pennsgrove, N. J.
Loshing, C. K. (re-election), Cleveland Elec. Illuminating Co., Cleveland, Ohio
Master, J. J., Saraya Sugar Factory, Dist. Gorakhpur, India
McLeod, A. M., R. H. Nichols Ltd., Ottawa, Ontario, Canada
Moodie, D. H., Ottawa Light Heat & Power Co., Ottawa, Ontario, Canada
Orr, W. W., Canadian General Elec. Co., Toronto, Ontario, Canada
Overby, E. H., Union Bag & Paper Corp., Savannah, Ga.
Price, H. N., General Elec. Co., Schenectady, N. Y.
Quirino, F., Consolidated Vultee Aircraft Corp., Fort Worth, Tex.
Rao, C. V., India Govt. Mint, Calcutta, India
Raube, W. C., General Elec. Co., Schenectady, N. Y.
Reese, F. H., LeValley McLeod Kinkaid Co., Inc., Elmira, N. Y.
Scott, C. E., Navy Dept., Bureau of Ships, Arlington, Va.
Slusser, L. M., 318 Dooly Bldg., Salt Lake City, Utah
Snowden, B. E. B., Southern Engineering Co., Atlanta, Ga.
Staples, D. R., Baldwin Locomotive Works, Eddystone, Pa.
Stavely, E. B., The Pennsylvania State College, State College, Pa.
Stone, C. R., William Hepburn & Co., Miami, Fla.
Treadway, T. F., Jr., Southern Engineering Co., Atlanta, Ga.
Voeller, R. L., General Elec. Co., Schenectady, N. Y.
Wadeson, H. L., Air Ministry, London, England
Walsh, R. E., Boston Edison Co., Boston, Mass.
Wakefield, J. A. P., Electricity Supply Comm., Salisbury, Southern Rhodesia
Welford, J., Box 1135 G P. O., New York, N. Y.
White, V. Mc., Westinghouse Elec. Intl., Co., New York, N. Y.
Wilson, G. M., Bureau of Reclamation, Washington, D. C.
Weston, W. J., Sir., W. G. Armstrong Whitworth Aircraft Ltd., Baginton, Coventry, England

48 to grade of Member

To Grade of Associate

United States, Canada, and Mexico

1. North Eastern

Albert, H. W., General Elec. Co., Schenectady, N. Y.
Amara, D., Massachusetts Inst. of Technology, Cambridge, Mass.
Bleuer, L. T., I. B. M. Corp., Endicott, N. Y.
Bonk, A. C., (Miss), General Elec. Co., Schenectady, N. Y.
Bryant, C. O., Jr., General Elec. Co., Schenectady, N. Y.
Cohen, R., General Elec. Co., Schenectady, N. Y.
Collins, C. C., General Elec. Co., Schenectady, N. Y.
Cooke, J. A., Westinghouse Elec. Corp., Buffalo, N. Y.
Crosby, H. A., Univ. of Maine, Orono, Maine
Dove, N. L., General Elec. Co., Schenectady, N. Y.

Duff, J. R., North Senior High School, Binghamton, N. Y.
Dutcher, J. L., General Elec. Co., Schenectady, N. Y.
Green, A. T., Niagara Elec. Corp., Buffalo, N. Y.
Haulman, G. M., General Elec. Co., Schenectady, N. Y.
Hawkins, J. W., General Elec. Co., Schenectady, N. Y.
Horton, E. M., N. Y. State Agr. & Tech. Institute, Canton, N. Y.
Huffman, B., Jr., General Elec. Co., Schenectady, N. Y.
Hamilton, R. L., General Elec. Co., Schenectady, N. Y.
Karnes, J. J., General Elec. Co., Schenectady, N. Y.
List, F. A., Jr., Westinghouse Elec. Corp., Cheektowaga, N. Y.
Lynch, E. D., Jr., Westinghouse Elec. Corp., New Haven, Conn.
Mengel, P. F., Central New York Power Corp., Potsdam, N. Y.
Miller, R. W., N. Y. State Agr. & Tech. Institute, Canton, N. Y.
Moen, B. C., General Elec. Co., Schenectady, N. Y.
Petraske, A. L., N. Y. State Inst. of Applied Arts & Sciences, Binghamton, N. Y.
Pomykata, J. C., General Elec. Co., Schenectady, N. Y.
Ramirez, J. A., General Elec. Co., Lynn, Mass.
Rottier, R. R., General Elec. Co., Schenectady, N. Y.
Sampson, E. S., General Elec. Co., Schenectady, N. Y.
Schirk, H. L., General Elec. Co., Schenectady, N. Y.
Siegel, R., General Elec. Co., Schenectady, N. Y.
Stratton, R. H., Central New York Power Corp., Potsdam, N. Y.
Swanson, R. M., Nashua Gummed & Coated Paper Co., Nashua, N. H.
Triolo, J. C., Stone & Webster Engg. Corp., Schenectady, N. Y.
Wanger, R. P., General Elec. East Lynn, Mass.
Ward, E. E., General Elec. Co., Schenectady, N. Y.

2. Middle Eastern

Anderson, E. A., Aluminum Co. of America, Cleveland, Ohio
Beatty, J. W., General Elec. Co., Philadelphia, Pa.
Bentley, C. C., Huntington Flood Wall, Huntington, W. Va.
Brown, F. J., Cleveland Elec. Illuminating Co., Cleveland, Ohio
Childers, L., Huntington Flood Wall, Huntington, W. Va.
Chope, R. E., United Engineers & Constructors, Philadelphia, Pa.
Craig, J. F., Westinghouse Elec. Corp., Toledo, Ohio
Dixon, R. W., General Elec. Co., Philadelphia, Pa.
Elrod, J. W., Pennsylvania Power Co., New Castle, Pa.
Feldsteen, J. J. (re-election), Apex Smelting Co., Cleveland, Ohio
Fischer, E. D., Huntington Flood Wall, Huntington, W. Va.
Gibel, V. A., Carnegie-Illinois Steel Corp., Duquesne, Pa.
Hale, R. W., Jr., General Elec. Co., Baltimore, Md.
Hirschfield, J., Naval Ordnance Lab., White Oak, Md.
Hoffman, F. W., Jr., Pennsylvania Power & Light Co., Hazleton, Pa.
Ickes, R. S., H. L. Yoh Co., Inc., Philadelphia, Pa.
Keenan, J. W., Allis Chalmers Mfg. Co., Pittsburgh, Pa.
Keller, D. J., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
La Marche, A. M. C. J., A. C. E. C. (Belgium) c/o Foreign Engg. Dept., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Leas, H. W., Metropolitan Edison Co., Reading, Pa.
Leiby, E. R., Keystone Pipe Line Co., Philadelphia, Pa.
Lichtenberg, J., Potomac Elec. Power Co., Washington, D. C.
Majercak, J. V., American Steel & Wire Co., Cleveland, Ohio
McLaughlin, K. M., Rural Electrification Admin., Washington, D. C.
Mellor, J. M., Ohio Brass Co., Mansfield, Ohio
Miller, D. D., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Rettig, H. W., The Cleveland Elec. Illuminating Co., Cleveland, Ohio
Rettig, R. G., General Elec. Apparatus Service Shop, Charleston, W. Va.
Rost, P. V., Cleveland Elec. Illuminating Co., Cleveland, Ohio
Seidler, W. A., Cleveland Elec. Illuminating Co., Cleveland, Ohio
Selser, H. M., Jr., U. S. Rubber Co., Philadelphia, Pa.
Seymour, W. C. (re-election), Pennyslvania Power & Light Co., Hazleton, Pa.
Shah, J. R., Natl. Bureau of Standards, Washington, D. C.
Sherrod, R. A., Westinghouse Elec. Corp., Sharon, Pa.
Smith. C. G., Electric Machinery Mfg. Co., Cleveland, Ohio
Smith, E. M., General Elec. Co., Philadelphia, Pa.
Snook, J. A., The Atlas Mineral Products Co., Mertztown, Pa.
Starceski, J. D., Allis-Chalmers Mfg. Co., Pittsburgh, Pa.
Steiner, H. M., General Elec. Co., Philadelphia, Pa.
Sturz, F. H., Elliott Co., Philadelphia, Pa.
Teore, K., General Elec. Co., Philadelphia, Pa.
Valenta, M. F., Westinghouse Special Products Engg., Pittsburgh, Pa.
Vollrath, W. W., Air Material Command, Wright Patterson Air-Base, Dayton, Ohio

3. New York City

Aldworth, J. G., Westinghouse Elec. Corp., New York, N. Y.
Barto, J. W. (re-election), 9115 Ridge Blvd., Brooklyn, N. Y.
Howe, J. C., Westinghouse Elec. Intl. Co., New York, N. Y.
Jongberg, J. B., Chemical Construction Co., New York, N. Y.
Keister, W., Bell Tel. Labs., New York, N. Y.
Loskot, G. A., Burns & Roe Inc., New York, N. Y.
Mendelson, A. W., General Cable, Corp., New York, N. Y.
Nelson, W. D., Voorhees, Walker, Foley & Smith, New York, N. Y.
Olesen, C. H., W. L. Maxson Corp., New York, N. Y.
Oper, M., Consolidated Edison Co. of N. Y., New York, N. Y.
Paullow, A., Consolidated Edison Co. of N. Y., New York, N. Y.
Pecora, J. J., Kellex Corp., New York, N. Y.
Persons, R. W., Ebasco Services, Inc., New York, N. Y.
Ronk, H. D. (re-election), Central Hudson Gas & Elec. Corp., Poughkeepsie, N. Y.
Smith, C. A. (re-election), Sylvania Elec., Flushing, N. Y.
Stanton, R. J., Induction Heating Corp., Brooklyn, N. Y.
Szmytkowski, M. A., Parsons, Brinckerhoff, Hall & MacDonald, New York, N. Y.
West, J. L., Columbia Univ., New York, N. Y.

4. Southern

Anderson, H. C., Jr., Southern States Equipment Corp., Hampton, Ga.
Askew, B. R., Georgia Power Co., Atlanta, Ga.
Blount, W. E., Georgia Power Co., Columbus, Ga.
Cawthon, R. L., Westinghouse Elec. Corp., Knoxville, Tenn.
Clark, J. H., Federal Power Comm., Atlanta, Ga.
Commagere, H. G., Byck Elec. Co., Inc., Savannah, Ga.
Edmonds, J. B., The Okonite Co., Birmingham, Ala.
Edwards, L. M., Savannah Elec. & Power Co., Savannah, Ga.
Frisch, E. A., Jr., Louisana Power & Light Co., New Orleans, La.
Ganesan, V., Univ. of Louisville, Louisville, Ky.
Greenway, W. H., Stone & Webster Engg. Corp., Alexandria, Va.
Heyl, R. A., Seabright Construction Co., Wheeling, W. Va.
Huff, E. S., U. S. Bureau of Mines, Norris, Tenn.
Johnston, R. L., Mississippi Power & Light Co., Jackson, Miss.
Jones, H. I., Jr., U. S. Air Force, Keesler Air Force Base, Miss.
Ketchey, C. F., Southern States Equipment Corp., Hampton, Ga.
Leary, F. B., Federal Power Comm., Atlanta, Ga.
Person, R. L., Marr & Holman, Arch., Nashville, Tenn.
Prime, J. B., Jr., Florida Power & Light Co., Miami, Fla.
Ripley, N. N., General Elec. Co., Williamston, N. C.
Rodgers, D. D., Southern Bell Tel. & Tel. Co., Miami, Fla.
Serice, J. A., Louisiana Power & Light Co., New Orleans, La.
Spencer, J. G., Jr., Florida Power & Light Co., Daytona Beach, Fla.
Spilker, C. J., Engineer Research & Development Labs., Fort Belvoir, Va.
Syrett, W. S., Louisiana Public Service Comm., Baton Rouge, La.
Tiller, J. K., C. & P. Tel. Co. of Va., Richmond, Va.

5. Great Lakes

Arnas, N. K., Jensen, Bowen & Farrell, Engrs., Ann Arbor, Mich.
Blythe, F. C., Westinghouse Elec. Corp., Springfield, Ill.
Bowers, V. L., Micro Switch Div., Freeport, Ill.
Dapkus, W. V., Consumers Power Co., Jackson, Mich.
Du Pasquier, F., Sargent & Lundy, Chicago, Ill.
Eckhardt, E. F. (re-election), Illinois Bell Tel. Co., Chicago, Ill.
Erickson, P. W., Illinois Bell Tel. Co., Chicago, Ill.
Erwin, D. B., Western Elec. Co., Chicago, Ill.
Ficke, J. H., Public Service Co. of No. Ill., Joliet, Ill.
Greenberg, M. L. (student), Univ. of Michigan, Ann Arbor, Mich.
High, D. N., Allis Chalmers Mfg. Co., Milwaukee, Wis.
Johnson, E. L., National Lock Co., Rockford, Ill.
Kramer, K. R., Wilson & Co., Inc., Chicago, Ill.
Lankford, C. E., Brown Engg. Co., Des Moines, Iowa
Lemke, A. R., Chicago Park District, Chicago, Ill.
Meuer, A. W., Illinois Bell Tel. Co., Chicago, Ill.
Middaugh, J. K., Illinois Bell Tel. Co., Chicago, Ill.
Rieker, C. M., Barber-Colman Co., Rockford, Ill.
Schmid, J. E., Public Service Co. of Indiana, Inc., Kokomo, Ind.
Strum, R. D., Rose Polytechnic Inst., Terre Haute, Ind.
Tjepkema, S., Commonwealth & Southern Corp., Jackson, Mich.
Trummel, V. E., Illinois Bell Tel. Co., Chicago, Ill.
Utterback, A. L., Public Service Co. of Northern Illinois, Maywood, Ill.
Waugh, W. R. (re-election), Indianapolis Power & Light Co., Indianapolis, Ind.
Western, R. E., South Dakota State College, Brookings, S. Dak.

6. North Central

Anderson, N. V., General Elec. Co., Denver, Colo.
Richardson, P. E., U. S. Bureau of Reclamation, Denver, Colo.

7. South West

Alexander, F. C., Vickers Elec. Div., Vickers Inc., St. Louis, Mo.
Ansley, J. E., Phillips Petroleum Co., Odessa, Tex.
Brown, F. W., Kansas Gas & Elec. Co., Wichita, Kans.
Caine, E. A., Price & Hawk, Lubbock, Tex.
Cooper, C. C., Kansas Gas & Elec. Co., Wichita, Kans.
Duncan, F. W., Southwestern Public Service Co., Amarillo, Tex.
Eck, L., Fargo Engg. Co., Austin, Tex.
Euler, E. J., S. C. Sachs Co., Inc., St. Louis, Mo.
Haught, H. E., Kansas Gas & Elec. Co., Wichita, Kans.
Henne, C. J., City Public Service Board, San Antonio, Tex.
Horan, T. M., Monsanto Chemical Co., St. Louis, Mo.
Johnston, J. H., Southwestern Public Service Co., Amarillo, Tex.
Manning, D. A., Line Material Co., Dallas, Tex.
Manning, H. L., Texas Elec. Service Co., Big Spring, Tex.
McCampbell, C. B., Jr., Los Alamos Scientific Labs. Albuquerque, N. Mex.
Oliver, W. M., Westinghouse Elec. Corp., St. Louis, Mo.
Payne, J. C., Priester Supply Co., Dallas, Tex.
Russell, M. L., Westinghouse Elec. Corp., Corpus Christi, Tex.
Summerfield, R. W., Kansas Gas & Elec. Co., Wichita, Kans.
Swinney, M. M., City Public Service Board, San Antonio, Tex.
Thompson, T. B., A & M College, Stillwater, Okla
Van Benthuysen, J., Murer & Smith, Clayton, Mo.
Warner, F. H., Fargo Engg. Co., Austin, Tex.
Whitaker, F. M., Public Service Co. of Oklahoma, Tulsa, Okla.

8. Pacific

Battaglino, J. P., Southern California Edison Co., Alhambra, Calif.
Brink, M. L., American Potash & Chemical Corp., Trona, Calif.
Coppin, C. C., III, Pearl Harbor Naval Shipyard, c/o FPO, San Francisco, Calif.
Cox, R., Town of Williams, Williams, Ariz.
Duerst, F. K., Westinghouse Elec. Corp., Los Angeles, Calif.
Hoyt, G. W., Pacific Gas & Elec. Co., San Francisco, Calif.
Humphrey, R. G., 11th Naval Dist. Hdqtrs., San Diego, Calif.
Jenkins, D. R., Westinghouse Elec. Corp., Los Angeles, Calif.
Johannessen, J. A., Johannessen & Girand, Phoenix, Ariz.
Kanter, E., U. S. Naval School, Monterey, Calif.
Lepper, R., Otis Elevator Co., San Francisco, Calif.
Lothringer, R. C., Consolidated Edison Co., Pasadena, Calif.
McKee, C. R., Westinghouse Elec. Corp., Los Angeles, Calif.
Messent, K. S. (re-election), Ralph M. Parsons Co., Los Angeles, Calif.
Meyer, O. R., California Inst. of Tech., Pasadena, Calif.
Mirabito, T. W., I. B. M. Corp., Los Angeles, Calif.
Mitchell, D. M., Citizens Utilities Co., Nogales, Ariz.
Morgan, A. H., Brundy, Engg. Co., Vernon, Calif.
Oldenburg, K. F., Clary Multiplier Corp., San Gabriel, Calif.
Rhoads, G. A., Safford Municipal Utilities, Safford, Ariz.
Schuyler, J. O., Stone & Webster Engg. Corp., Salinas, Calif.
Seemann, C. H., Graham County Elec. Coop., Pima, Ariz.
Smith, C. W., Elec. Contractor, Santa Barbara, Calif.
Thorpe, D. W., 6911 Mt. View, Huntington Park, Calif.
Wallace, H. M., California Elec. Power Co., Riverside, Calif.
Withey, K. J., Dept. of Water & Power, Los Angeles, Calif.
Wood, A. E., Jr., Leach Relay Co., Los Angeles, Calif.

9. North West

Baker, H. L., U. S. Bureau of Reclamation, Billings, Mont.
Engvall, L. R., Bureau of Reclamation, Coulee Dam, Wash.
Feinstein, H., Boeing Airplane Co., Seattle, Wash.
Simpson, T. E., City of Tacoma Light Department, Tacoma, Wash.
Thompson, W. S., Univ. of Portland, Portland, Oreg.

10. Canada

Anderson, R. G., Stewart Elec. Co. Ltd., Winnipeg, Manitoba, Canada
Bergenstein, E. G., Canadian General Elec. Co., Toronto, Ontario, Canada
Conlin, M. D., Canadian General Elec. Co., Toronto, Ontario, Canada
Korlie, W., English Elec. Co. of Canada Ltd., Calgary, Alberta, Canada
Lupu, M., Northern Elec. Co., Ltd., Montreal, Quebec, Canada
Mackin, G. F., British Columbia Elec. Railway Co. Ltd., Vancouver, British Columbia, Canada
Natarajan, K. S., Madras, India, c/o Canadian General Elec. Co. Ltd., Peterborough, Ontario, Canada
Price, F. O., Hydro Elec. Power Comm. of Ontario, Toronto, Ontario, Canada
Ross, D. A., G. E. X-Ray Corp. Ltd., Montreal, Quebec, Canada

Elsewhere

Blydt, C. B., Samkjoringen, Oslo, Norway
Cassidy, J. G., Brown-Boveri (Ireland) Ltd., Dublin, Ireland
Magill, B., Messrs. Brown-Boveri (Ireland) Ltd., Dublin, Ireland
Midson, M. D., Launceston Tech. College, Launceston, Tasmania, Australia
Nanda, Y. R., Escorts (Agents) Ltd., New Delhi, India
Padilla, A. R., Dept. of Education, Utuado, Puerto Rico
Tiruvengalam, S., College of Engineering, Guindy, Madras, India
Wilhelmsen, F., Association of Norw. El. Power Cos., Oslo, Norway

Total to grade of Associate
United States, Canada, and Mexico, 215
Elsewhere, 8

Alco-GE Developmental Gas Turbine-Electric Locomotive Enters Service on Union Pacific

The first gas turbine-electric locomotive to be built and operated in the United States, a 4,500-horsepower unit, has completed preliminary road tests, and will see freight service with the Union Pacific Railroad, beginning this summer. Engineered jointly by the American Locomotive Company and the General Electric Company, the new locomotive is the product of five years' research.

Road trials and laboratory tests to date show the gas-turbine powered system to compare favorably in many respects with the diesel engine as a prime mover. One index of locomotive performance is "horsepower per foot of length." For many years, the maximum height and width of railroad cars has been set by clearance requirements of tunnels, bridges, and so on. Thus, the only general dimensional variable is over-all length. Compared to the diesel-electric figure of 30 horsepower per foot of length, it is expected that the gas-turbine-electric unit will develop 53 horsepower per foot. Based on this general index, it is believed that the gas turbine will perform nearly twice as efficiently as a comparable diesel engine.

The locomotive looks like a conventional electric locomotive. It has the same type of cab and running gear. The new part is the gas-turbine power plant which has been designed for electric drive, and put into existing space and weight limitations.

Specifically, the locomotive is of single-cab construction with an operating station in each end and has *B-B-B-B* running gear. It develops 53 horsepower per foot of length (as mentioned), weighs 500,000 pounds, and has a continuous tractive effort of 68,500 pounds at a speed of 20.5 miles per hour. It is 83 feet $7^1/_2$ inches long inside of knuckles, 14 feet $3^1/_2$ inches high over roofsheet, and 10 feet 7 inches wide over hand rails. Geared for a speed of 79 miles per hour, the locomotive carries enough fuel for a run of 12 hours at 4,500 horsepower.

In operation, the gasses produced by the turbine are harnessed within the power plant and the resultant power is transmitted electrically to drive the wheels. The compressor, combustion chamber, and turbine are of in-line construction. Air is drawn through a compressor into several combustion chambers. Fuel is injected and the mixture burns, raising the temperature of the compressed air. Resulting gasses expand and move at great velocity against the turbine blades, turning the shaft. The shaft drives both the power-plant compressor and the generator. Power from the generator is supplied to eight tractions motors, each of which drives one of the locomotive's eight axles. The gas-turbine power plant itself is rated at 4,800 horsepower, with 4,500 horsepower available for traction, and the residual power used to drive auxiliaries.

Two big unknowns will be evaluated in the locomotive's road service in the West. One is life expectancy of the unit, and the concomitant factor of how much time can be permitted to elapse between major overhauls.

The second is how economically the gas turbine electric system will handle fuel. Although the present model is fired by bunker *C* oil, it is thought that eventually operating costs may be reduced further by burning low-grade fuels, such as coal.

First RCA Multiple-Outlet Television Systems Installed

Initial installations of the Radio Corporation of America's first multiple-outlet television system for multiunit structures, such as apartment houses, hotels, and office buildings, have been completed in New York, N. Y., and Philadelphia, Pa.

Designed to accommodate a large number of television receivers within a single building, the new system, known as "Television Antenaplex," includes either a separate antenna for each channel in a given area, or merely a separate cross-arm for each station, mounted on a single mast, depending on the location of local transmitters in relation to the receiver site. It obviates the impractical alternative of installing a large number of individual antennas on the roof—one for each receiver in the building—with the adverse effect each has on the other due to interaction.

Installations already made include such apartment and hotel structures as the Rittenhouse Plaza, in Philadelphia, and 880 Fifth Avenue, 834 Fifth Avenue, and the Park Lane Hotel in New York. Department stores employing the new system include Gimbel Brothers, in Philadelphia, and Macy's in both New York and White Plains.

In addition to television service, Television Antenaplex also can feed both amplitude- and frequency-modulation radio signals to sets that provide for both television and radio reception. Any television set which meets the Radio Manufacturers Association standards for reduction of interference can be connected with this system.

At the present time the Television Antenaplex system is available only in a few eastern television areas. It is expected that the system will be available on a nation-wide basis in the latter part of the year.

List of Technical Translators, Translations Pool, Now Available

Solution of the problem of locating persons with special language skills for translating scientific and technical articles is forecast in the announcement of the establishment of a Directory of Translators by the Science-Technology Group of Special Libraries Association. The directory is operated as a free service to bring together clients having translation problems and language specialists competent in various subject fields in science and technology. The directory has been housed at the Southwestern Research Institute, San Antonio, Tex., under the management of Wayne Kalenich, librarian.

Individuals or firms needing qualified translators are invited to address inquiries to Mr. Kalenich, and translators are urged to place their qualifications on file with the directory. Twenty-three languages already are included among the specialists listed there, and it is hoped soon to expand the directory to include translators for all fields of knowledge. While no data concerning interpreters have been collected as yet, such information is solicited.

Mr. Kalenich also conducts the Special Libraries Association Translations Pool, which records the existence of technical translations within private files in the United States, and the conditions of their loan or purchase. This pool was created in 1945 to prevent or reduce unnecessary dupli-

A yard crew looks over the Alco-GE gas turbine-electric locomotive. Most of the area of the cab sides, except where there are sand boxes, is made up of air filters. This insures an ample supply of filtered air for combustion in the power plant

Coaxial-Cable Progress

Bell Telephone Laboratory engineers, inventors of the coaxial cable, compare first experimental model with newest type. At left, Lloyd Espenschied (F '30) holds section of cable installed at Phoenixville, Pa., late in 1929. H. A. Affel (F '41) holds portion of modern 8-tube cable. One pair of eight tubes can carry 600 simultaneous telephone conversations or two television programs

cation in the translation of scientific articles. About 3,000 translations already have been indexed in the pool. Persons contemplating the translation of a technical article are urged to make a preliminary check with Mr. Kalenich to be sure that such a translation is not already available.

Professional Guide for Engineers Now Available from ECPD

A guide slanted to the needs of the young engineer, written by the late Dr. William E. Wickenden, for 18 years president of Case Institute of Technology, has been published by the Engineers' Council for Professional Development (ECPD). The book, titled "A Professional Guide for Junior Engineers," was begun by Dr. Wickenden in 1942. He died in 1947 before he completed the final version. G. Ross Henninger, then editor of *Electrical Engineering*, and now director of publications of the Illuminating Engineering Society, undertook the task of editing the final version.

The book presents the philosophy and engineering ethics a young engineer needs for success, as viewed by Dr. Wickenden. It opens with a historical survey of the engineer's heritage, going back to Tubal Cain, and traces the beginnings of engineering societies. Wickenden depicts every aspect of the engineering profession, what the young engineer can expect to find, the difference between a trade and a profession, professional relationships, finally ending the book with his famous essay on a philosophy of life, "The Second Mile."

Addenda to the book are "Faith of the Engineer," a credo accepted by the ECPD, a recommended reading list for junior engineers, a self-appraisal questionnaire, and the canons of ethics for engineers. Copies may be obtained from the Engineers' Council for Professional Development, 29 West 39th Street, New York 18, N. Y., for one dollar. Quantity purchases are available at a discount.

Revamp Military Standards Agency to Allow Air Force Participation

Under the terms of a new charter recently signed by the assistant secretaries of the three military services, the government body organized in December 1943 as the Army-Navy Electronic Standards Agency has been reconstituted as the "Armed Services Electro Standards Agency." The change provides for official participation by the Air Force, which became a separate component of the National Military Establishment under the provisions of the National Security Act of 1947.

Employing 126 persons, the agency occupies five buildings just outside the main area of Fort Monmouth, N. J., near the Signal Corps Engineering Laboratories. Sales and technical representatives of radio-electronics manufacturers are welcome to visit the agency at any time, according to its officials, to obtain first-hand information on the work it is doing. The codirectors of the Agency are Colonel Louis J. Tatom, Signal Corps, and Captain Henry E. Bernstein, United States Navy. Clayton J. Held represents the Air Materiel Command of the Air Force.

The mission of the Standards Agency is four-fold: to reduce the number of styles and types of electronic components used in the manufacture of military equipment of all kinds; to insure their quality and dependability; to achieve a high degree of interchangeability; and to designate approved sources of supply.

Considerable progress in alleviating the war-born confusion over electronic parts is being made. For instance, three standard crystal holders, to meet any foreseeable requirement, have been adopted to replace 350 different holders which were used formerly. A single standard wire-wound resistor takes the place of 33 former nonstandard types. Audio and power transformers that required more than 10,000 different sizes and shapes of cases can now be accommodated in only 22 standard containers. Measuring instruments and tubes have received the benefit of special attention. More than 37,500 types of meters have been reduced to 3,700 standard types, and 3,000 types of vacuum tubes have been cut down to 800 for replacement purposes and down to about 200 for new applications.

Vannevar Bush Honored by Industrial Research Institute

Dr. Vannevar Bush, who as chairman of the Office of Scientific Research and Development (OSRD) was "chief of staff" for American science during World War II, has received the 1949 medal of the Industrial Research Institute. The award was presented at a luncheon in Washington, D. C., by H. W. Graham, vice-president and director of technology of the Jones and Laughlin Steel Company, and senior past-president of the institute. E. W. Engstrom, institute president, and vice-president in charge of research, Radio Corporation of America Laboratories, presided.

With the medal, Dr. Bush received a scroll bearing the following citation: "Dr. Vannevar Bush for his leadership in the Office of Scientific Research and Development, in marshalling industrial and academic research and co-ordinating it with the military effort in the common defense, developing an instrument of government so effective as to provide a pattern for continued service."

Dr. Bush, who has been president of the Carnegie Institution in Washington since 1939, became chairman of the National Defense Research Committee in 1940 and headed the OSRD the following year. He resigned from the government organization last year in order to devote more time to the presidency of the Carnegie Institution. From 1919 to 1939, Dr. Bush was associated with the Massachusetts Institute of Technology, first as a professor and later as vice-president and dean of engineering.

The Industrial Research Institute was organized in 1938 under the auspices of the National Research Council and now has a membership of 110 companies, with research staffs numbering more than 25,000 persons.

Motion Picture Engineers Propose Name Change, Honor Hyndman

The close and fast-growing relationship between motion picture engineering and television engineering has been recognized in a proposal to change the name of The Society of Motion Picture Engineers to the Society of Motion Picture and Television Engineers, it was announced at the Society's 65th semiannual banquet in New York, N. Y. A recommendation that this change be made was received favorably by the Board of Governors of the society.

Since the change would require an amendment to the society's constitution, notice of the recommendation is being sent to all members and the question will be brought up for discussion at the 66th Semiannual Convention, to be held at the Hollywood-Roosevelt Hotel, in Hollywood, Calif., next October 10–14. This will be followed by a mail ballot.

Highlight of the banquet was the presentation of a special award, in the form of a bronze placque, to Donald E. Hyndman, a past president of the society and chairman of its Theater Television Committee, in recognition of "his unselfish, outstanding personal endeavors as an officer of the society, and his continued enthusiastic guidance in improving the prestige and financial stability of the society by increased participation of industry in sustaining memberships."

Con Edison Man Lectures British IEE. Ward F. Davidson (A '14, F '26), of the Consolidated Edison Company of New York, Inc., New York, N. Y., delivered the Supply Section Annual Lecture in London, England, on May 11, 1949. Speaking under the auspices of the Institution of Electrical Engineers, his topic was "Plant Co-ordination—an Example of Co-operation." He discussed procedures that have been developed in the United States for solving the problems of physical and inductive co-ordination of power and communications systems, and presented solutions that have been found to particular problems. The Supply Section Annual Lecture traditionally is given by an engineer from outside of Great Britain. P. M. J. Ailleret of France gave the first lecture in 1937. Mr. Davidson is the first American speaker in the series.

S. D. Cornell Named to Head RDB Division. S. D. Cornell has been named director of the Planning Division, Research and Development Board (RDB). Dr. Cornell has been a member of the Planning Division since 1946, having served as deputy director and acting director since February of this year. For a short while, he was acting executive director of the RDB Committee on Guided Missiles. Prior to this, he was deputy secretary of the Joint Chiefs of Staff Committee on Guided Missiles. During the war, he was on active duty with the Navy and was assigned to the Headquarters of the Commander-in-Chief, United States Fleet, and the Office of the Chief of Naval Operations. In these assignments, he was concerned with the development and production of an antiaircraft tracer fire-control trainer known as Gunnery Trainer Mark 1, and in new weapons research and development. Entering on duty as a lieutenant (junior grade), he rose to the temporary rank of commander before returning to inactive duty in 1946. Dr. Cornell was graduated from Yale University in 1935. He held a Sloane-Silliman graduate fellowship at Yale for three years, receiving his doctorate in physics in 1939. From 1938 to 1942 Dr. Cornell held the position of physicist in the Development Department of the Eastman Kodak Company.

Future Meetings of Other Societies

American Institute of Chemical Engineers. September 6–9, 1949, Mount Royal Hotel, Montreal, Quebec, Canada.

American Society of Mechanical Engineers. Fall meeting. September 28–30, 1949, Erie, Pa.

Illuminating Engineering Society. National Technical Conference. September 19–23, 1949, French Lick, Ind.

Instrument Society of America. Annual meeting and exhibit. September 12–16, 1949, Municipal Auditorium, St. Louis, Mo.

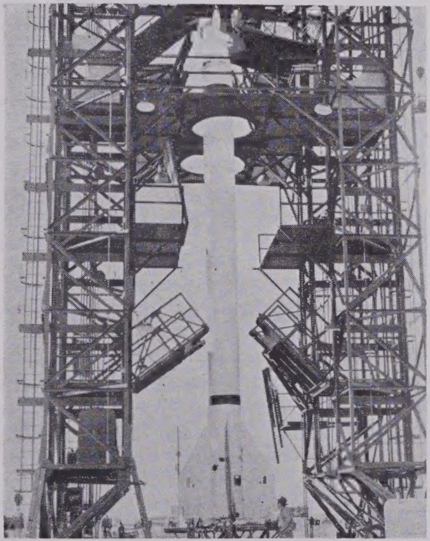
National Electronics Conference. September 26–28, 1949, Edgewater Beach Hotel, Chicago, Ill.

National Safety Council. September 24–28, 1949, Morrison Hotel, Chicago, Ill.

Practising Law Institute. Conference on Current Problems in Patent Law. Annual summer session. July 18–22, 1949, Hotel Statler, New York, N. Y.

Scottish Industries Exhibition. September 1–17, 1949, Kelvin Hall, Glasgow, Scotland.

First Viking Rocket



This is the Viking, first American-designed high-altitude research rocket, being prepared for flight at White Sands Proving Grounds, Las Cruces, N. Mex. Technicians can reach all parts of the 45-foot rocket from platforms on the movable gantry. Launched late last spring, this first in the series of ten Viking rockets to be built for the Navy reached an altitude of $51^1/_2$ miles and a speed of 2,240 miles per hour. Constructed by the Glenn L. Martin Company, the Viking has a power plant designed by Reaction Motors, Inc., and uses liquid oxygen and alcohol as fuel

LETTERS TO THE EDITOR

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers. Publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

The Transistor

To the Editor:

In reference to the article entitled "The Transistor—A New Semiconductor Amplifier," by J. A. Becker and J. N. Shive, in the March issue of *Electrical Engineering* (*p 215–21*), it may be of interest to mention that the available gain, the maximum available gain, and the maximum available gain when $r_b=0$ should be as follows:

Available power gain =

$$\frac{R'_{21}{}^2R_{22}}{(R_{22}+R_{22}')^2(R_1+R_{11}')-R_{12}'R_{21}'(R_{22}+R_{22}')}$$

Maximum available power gain =

$$\frac{R_{21}'^2R_{22}}{(R_{22}+R'_{22})^2(R_{11}+R_{11}')-R_{12}'R'_{21}(R_{22}+R_{22}')}$$

$$\underset{r_b=0}{\text{Maximum available power gain}}=\frac{r^2{}_m{}^2}{8r_er_c}$$

H. G. POSTHUMUS

(United States Naval Ordnance Plant, Indianapolis, Ind.)

Brain as a Computing Machine

To the Editor:

Professor McCulloch has written an extremely valuable and timely contribution to the understanding of human thinking in his "Brain as a Computing Machine" in the June 1949 issue (*pp 492–7*).

The subject is so vast and man's comprehension of how he thinks so limited, that perhaps some comment would be in order.

The ten billion unit cells of the cerebrum or thinking part of the brain are supplemented by four quadrillion others in the cerebellum. Each of these cells have at least 100 ciliary connections with adjacent cells, the whole forming an extraordinarily complicated network or telephone switchboard where the total number of combinations possible is of the order of $10^{15,000,000}$.

It is important to remember that this figure expresses only combinations and not concrete particles, since no such number of particles could exist, even in the cosmos.

This foregoing concept is important, for he states memory snapshots are of the order of 10^{10}, which figure is far too small to account for the daily panorama of vision which consists not of discrete snapshots but an infinity of ever-changing views. Each of his ten billion snapshots are really cinematic recordings consisting of many, many "stills."

Thus we come to Stroud's: "Traces left by experience are quantized alterations of protein molecules some 10^{21} in number." As there are not a sextillion cells or protein molecules either—in the human brain, it follows we have what amounts to microfilm recordings on unit protein molecules, or more probably some portion of the memory recording is etched on each of many units, the entire mosaic being rescanned only when all components are functioning harmoniously through the intercellular nerve-lines.

He says, "The genes do not contain enough information to specify all the connections of our nerve cells," and this statement must be questioned.

The genes specify the foetus, a living growing entity, which specifies the embryo, which specifies the body, which specifies the later growth of teeth, mammary glands in females, and reproductive organs in both male and female. In each case the pattern or seed of the later evolution already existed in the previous entity, that is, the secondary, tertiary bodies, and so forth. We must conclude the original pattern existed in the gene, even though our chemistry does not discovery it.

Professor McCulloch's article convinces me that the final machine can create yet more complicated machines. In other words, we can train our brains to function as automatic computing machines as has been illustrated by the rare mathematical wonders who can compute instantly large numerical products in their heads.

D. J. STRUVEN (A '43)

(Westinghouse Electric Corporation, Bloomfield, N. J.)

4-Terminal Network

To the Editor:

I want to congratulate Jack Ruina, of Brooklyn Polytechnic Institute, for his beautiful solution to my essay of November (*EE, Nov '48, p 1073*), which he gives in his letter (*EE, May '49, p 468*). It is very similar to that sent me by Stanley R. Jordan, of Dayton, Ohio, and which I described in my letter (*EE, May '49, p 468*).

I am afraid that J. C. Stewart, of Sydney, Australia, (*EE, May '49, p 468*) will like this solution by Ruina, which makes active use of only three of the six transformers even less than he does my solution (*EE, Dec '48, p 1073*) which actively uses four of the six transformers. I can offer no defense to Mr. Stewart's criticism. It is a question of interpretation of the "rules of the game." When I offered six transformers to accomplish a certain task, I thought I was stipulating only that no more than these transformers should be used. Mr. Stewart, however, thinks I also was stipulating that no less than all six of these should be actively used. If his interpretation of the "rule of the game" is accepted, then he wins. He does show a circuit which utilizes all six transformers in a completely symmetrical way.

Concerning the last paragraph of Mr. Stewart's letter, I might observe that the windings of a delta-connected polyphase transformer usually are said to be connected to three points and not six, and that the windings of an energized star-connected polyphase transformer with floating neutral commonly are said to be connected to three points and not four.

J. SLEPIAN (F '27)

(Associate Director, Westinghouse Research Laboratories, East Pittsburgh, Pa.)

To the Editor:

Dr. Slepian, in his letter to the editor (*EE, May '49, p 467*), challenges my solution (*EE, Feb '49, p 86*) to his electrical essay "4-Terminal Network" and compels me to present the calculations in more detail. The essay has a number of solutions requiring four or *more* transformers. This is the reason I felt that a specific solution using six transformers was called for.

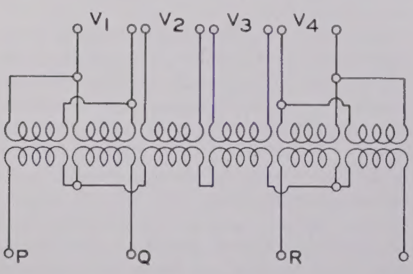


Figure 1

As to my solution, the requirement is that transformers *1* and *2* as numbered from left to right, and transformers *5* and *6* be energized at different frequencies. Voltages of transformers *3* and *4* are in quadrature with the foregoing two voltages. Thus, for example, the voltages may be as follows:

$$E_1 = 70.7 \sin \omega t$$
$$E_2 = 70.7 \sin \omega t$$
$$E_3 = 70.7 \sin 3\omega t$$
$$E_4 = 70.7 \cos \omega t$$
$$E_5 = 70.7 \cos 3\omega t$$
$$E_6 = 70.7 \cos 3\omega t$$

In the diagram of Figure 1 of my letter polarities of the transformers are assumed to be the same. Voltages PQ and RS are double the voltage of one transformer because of the parallel-primary series-secondary connections and are of single-frequency form:

$$E = 2(70.7 \sin \omega t) = 141.4 \sin \omega t$$

The effective value of the foregoing is 100 volts.

The other voltages are the variants of the following expression:

$$E = \pm 70.7 \sin \omega t + 70.7 \cos \omega t + 70.7 \sin 3\omega t \pm 70.7 \cos 3\omega t$$

All the variants of the foregoing expression reduce to:

$$E = 100 \cos(\omega t \mp 45 \text{ degrees}) + 100 \sin(3\omega t \pm 45 \text{ degrees})$$

The effective value of each variant of the foregoing is

$$E = \sqrt{1/2(100^2 + 100^2)} = 100 \text{ volts}$$

May I again compliment Dr. Slepian on his contributions to the enjoyment of *Electrical Engineering.*

A. A. KRONEBERG (F '48)

(Southern California Edison Company, Los Angeles, Calif.)

Homocharge of Electrets

To the Editor:

The mechanism by means of which the homocharge of an electret is produced (charge of the same sign as that of the polarizing electrode) has not yet been clarified. Because of the increasing interest in electrets, it is believed that the following comments might be helpful to investigators in the field.

As pointed out in previous papers[1,2], there are indications in favor of an explanation of the homocharge by means of the internal mechanical stresses in an electret. There exists, however, a more direct and very simple possible explanation which follows.

The first observable charge, essentially caused by ionic space charges, is a heterocharge, having a sign opposite to that of the polarizing electrode. This charge persists usually for about a week before it gives way to a permanent homocharge. In carnauba wax without admixtures the heterocharge is either of very brief duration or not measurable at all, but even in this latter instance it is reasonable to suppose that it did exist for a short period.

Immediately after removal of the polarizing voltage, this heterocharge produces a large internal electric field, opposite in sign to that of the polarizing field. This is the analogue of the internal demagnetizing field in a permanent magnet. Its magnitude may be even greater than that of the external field because the latter is limited in magnitude by the relatively low ionizing field stress of air. The internal field produces two effects. First, migration of ions will start, neutralizing the ionic heterocharge, which accordingly decays, as observed. Next, the dipoles, originally oriented so as to contribute to the heterocharge, will be reversed, with the result that they produce a homocharge. It is likely that in the first period following the making of the electret, the dipoles are not yet crystallized to form domains so that a rotation can take place relatively easily. In the later stages, when the structure is more stable, an electric field has less influence on the orientation. When the heterocharge has decayed, the reversed dipoles produce a homocharge, as observed.

This rather simple explanation could be tested experimentally. One possible method would be to leave the original polarizing field on for some time, perhaps several days, after the wax has solidified. In this manner the external field would overcompensate the internal field of the heterocharge and a reversal of the dipoles might be prevented. In an electret prepared in this manner a permanent heterocharge would prevail. While a positive outcome of this experiment would speak in favor of the explanation suggested, a negative outcome would not necessarily permit a definite conclusion.

REFERENCES

1. **Andrew Gemant.** *Philosophical Magazine* (London, England), volume 20, 1935, page 929.

2. **Andrew Gemant.** *Physics Today* (New York, N. Y.), volume 2, March 1949.

ANDREW GEMANT

(Research Department, The Detroit Edison Company, Detroit, Mich.)

Voltage Notation Conventions

To the Editor:

The article, "Voltage Notation Conventions," by Reed and Lewis (*EE, Jan '48, pp 41–8*), and the subsequent nine or more letters of discussion express not only a need for agreement on symbols, but also a need for agreement on meanings. It appears that the various authors use the three terms "potential difference," "electromotive force," and "voltage" rather indiscriminately to stand for three different concepts and also for various combinations of these. It seems doubtful that engineers really can adopt a standard symbol for voltage without first adopting a standard meaning for the term "voltage."

The three distinct concepts mentioned are as follows (with the names originally given to them):

1. Potential difference—difference of potential energy per unit positive charge between two points.

2. Electromotive force—work necessary to move a unit positive charge through certain specified circuit elements.

3. Voltage—that which is measured by a voltmeter connected to two terminals.

Since work done is equal to change in potential energy only when all other forms of energy remain constant, potential difference is not usually equal to electromotive force.

As currently used, the term "voltage" usually means electromotive force, though it is sometimes restricted to the electromotive force across a passive impedance. Often, however, it is used in such a way as to mislead unwary readers into thinking that potential difference is meant. For example, the statment often is made that when a voltage appears between two terminals then the positive terminal is at a higher potential than the negative terminal. In such cases, however, the word "potential" is not used with its original meaning. "Potential" then means, not potential energy per unit positive charge, but rather an undefined "something" which is assumed to be analogous. Sometimes, even, the term "potential difference" is used instead of the term "voltage," but electromotive force is meant, nevertheless. Likewise the terms "voltage drop" and "voltage rise" mean simply voltage (electromotive force). It appears, however, that some engineers fail to distinguish among the three concepts listed in the foregoing and hence use the terms "voltage," "potential difference," and so forth, to mean a poorly defined mixture of all three.

At present there appear to be two reasons for distinguishing between the last two of the three concepts. One reason is that many engineers wish to distinguish between the electromotive force across a source and the voltage across a passive load. Such a distinction is logically acceptable but it does not appear to have any counterpart in physical reality. The other reason is that disagreement exists on a question of direction versus polarity. Reed and Lewis state that voltage does not have the property of direction, but has polarity. Some engineers feel, however, that electromotive force does have the property of direction.

It appears, then, that standardization is needed on meaning as well as on symbolism. This should be easy, since only a minimum area of agreement is needed. The foregoing discussion is suggested as a possible basis for such minimum agreement.

In using the terms "voltage" and "electromotive force" let us adopt the practice of designating the positive and negative terminals either by plus and minus signs or by directed arrows. Let us call voltages and electromotive forces positive when they are such that if passive loads were connected to their terminals, then positive currents would flow from the positive terminals to the negative terminals. If we must use the terms "potential difference," "voltage drop," and so forth, as synonyms for voltage then let us not therefore falsely introduce potential energy into our reasoning.

Conventional practice needs to be established for two questions of usage, both requiring arbitrary decisions. One is the question of double subscript symbols discussed by Reed and Lewis. The other is the need for an unambiguous meaning of the phrase—voltage between points "*a*" and "*b*"—which does not state whether "*a*" or "*b*" is the positive terminal. A good practice in this case would be always to give the positive terminal first. Thus, let us have the foregoing phrase, and the alternative one—the electromotive force from "*a*" to "*b*"—always mean that "*a*" is the positive terminal. If this practice is adopted, then, logically, the recommendations of Reed and Lewis in regard to double subscripts should be adopted also.

EDSON W. SKIFF (A '42)

(Research engineer, University of California, Berkley Calif.

Electromagnetic Induction

To the Editor:

I would like to point out an error in George I. Cohn's article, "Electromagnetic Induction" (*EE, May '49, pp 441–7*). He states that the flux-linkage law, $e=-\frac{d\phi}{dt}$, when applied to the Faraday disk, gives a zero result because no flux links the circuit. His error lies in not giving proper consideration to the circuit in question. It is true that, as Mr. Cohn states, no flux links the circuit *ABCDO*, when the disk is at rest. However, when the disk begins to rotate, the circuit is deformed and at some time "*t*" will have the configuration *ABCDD'O*. The flux-linkages at that instant will be

$$d\phi = B\pi R^2 \frac{d\theta}{2\pi}$$

or

$$d\phi = \frac{BR_{z}}{2}\, d\theta$$

Hence,

$$E = -\frac{BR^2}{2}\frac{d\theta}{dt} = -\frac{BR^2}{2}\,\omega \tag{1}$$

which is the same result as was obtained by applying the flux-cutting law.

What leads one astray in first considering this problem is the apparent rectangularity of the circuit; however, to maintain such a rectangle as the disk rotates, it is necessary to introduce a new radial element in the position *OD* at every instant. To change circuit elements in such a manner would be inadmissible in general, I should think, and in this instance is certainly not permissible because an incorrect result is obtained.

I would like to add that the same result as in equation 1 is obtained if we replace the disk by a conducting ring of the same diameter as the disk, and attach a radial conductor to the point *O* with its outer end sliding along the ring; this conductor to rotate about the axis of the ring.

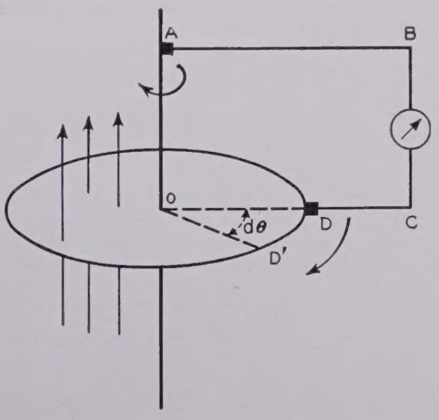


Figure 1

NORTON SAVAGE (A '41)

(Assistant Electrical Supervisor, United Engineers and Constructors, Sewaren, N. J.)

Locomotive Traction Generator

To the Editor:

I would like to make the following remarks on the most interesting paper, "The Locomotive Traction Generator Comes of Age" (digest, *EE, Jun '48, p 550*) by Richard Lamborn.

The necessary range of "wrap-around" of a d-c traction generator depends to an important degree on the speed-current characteristics of the traction motors. By providing an unusually large air gap for the traction motor very often much more favorable conditions are obtained, as the steeper increase of motor speed means less increase of generator voltage required. This saving of range or kilovolt-amperage of generator is usually more important than the small increase of size or gear ratio of traction motor to compensate for the increased air gap. I do not know if this method of layout, which proved very successful in continental Europe before the past war and was suggested for the first time more than 20 years ago by O. Zadnik of Vienna, Austria, is known and used in the United States.

Choosing the rated (or continuous) output of the generator in regard to that of the traction motor depends to a large extent on the design of those machines and the service to be performed. Self-ventilated traction motors of locomotives for heavy slow-speed shunting operations sometimes have to be designed for a larger rated current than the generator, allowing for the inferior ventilation of the motor during shunting operations.

B. GERSTMANN (A '41)

(Australian Block and Chain Company, Melbourne, Victoria, Australia)

NEW BOOKS • • • • •

The following new books are among those recently received at the Engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

PHYSICAL ASPECTS OF COLOUR. (Philips Technical Library.) By P. J. Bouma. N. V. Philips Gloeilampenfabrieken, Eindhoven, Netherlands. Distributors for United States and Canada, Elsevier Publishing Company, New York, N. Y.; for Great Britain, Cleaver Hume Press Ltd., London, England, 1948. 312 pages, diagrams, charts, tables, $9^1/_4$ by 6 inches, cloth, $5.50. Approaching the subject from the viewpoint of experimental physics and illuminating engineering, this book surveys the theory of colorimetry and its applications to practical problems. An introductory discussion of classification, a consideration of the theoretical basis of color measurement and color calculation, the practice of color measurement, and a survey of the aspects of science and technology in which practical applications are made, are included.

PRACTICAL ANALYSIS, GRAPHICAL AND NUMERICAL METHODS. By Fr. A. Willers, translated by R. T. Beyer. Dover Publications, New York, N. Y., 1948. 422 pages, diagrams, charts, tables,

$9^{1}/_{2}$ by 6 inches, cloth, \$6. The numerical and graphical and many of the instrumental methods of analysis which provide solutions useful to the practical scientist. The first chapter deals with the special problems encountered in calculating with approximate numbers. The succeeding chapters cover standard methods of interpolation, methods of numerical differentiation, practical determination of the roots of single algebraic equations and systems of linear equations, empirical formulas, and the graphical and numerical integration of differential equations.

PRINCIPLES OF MATHEMATICAL PHYSICS. By W. V. Houston. Second edition. McGraw-Hill Book Company, New York, N. Y., Toronto, Ontario, Canada, London, England, 1948. 363 pages, diagrams, charts, tables, $9^{1}/_{4}$ by 6 inches, cloth, \$5. Written to give the student some competence in the techniques of classical mathematical physics, a thorough knowledge of elementary physics, analytical geometry, and calculus is assumed. Amplified to include numerous illustrative examples completely or partly developed in the text, the addition of drawings, and some minor rearrangements of material. The chapters on electricity and magnetism have been considerably expanded and revised, and the MKS system of units has been used throughout.

RADAR PRIMER. By J. L. Hornung. McGraw-Hill Book Company, New York, N. Y., Toronto, Ontario, Canada, London, England, 1948. 218 pages, illustrations, diagrams, maps, $8^{1}/_{4}$ by $5^{1}/_{2}$ inches, cloth, \$3.50. Of value to those interested in obtaining a fundamental understanding of radar, this well-illustrated book presents basic principles and peacetime applications. Technical vocabulary and scientific theory are kept to a minimum. All the important areas of radar are explored, and the essential features of television, loran, and sonar are supplied.

RADIO AT ULTRAHIGH FREQUENCIES, Volume II (1940–1947). Edited by A. N. Goldsmith and others. Published by RCA Review, Radio Corporation of America, RCA Laboratories Division, Princeton, N. J., July 1948. 485 pages, illustrations, diagrams, charts, tables, $9^{1}/_{4}$ by 6 inches, cloth, \$2.50 plus 20 cents postage to foreign countries. This compilation of original and reprinted papers is presented in seven sections: antennas and transmission lines, propagation, reception, radio relays, microwaves, measurements and components, and navigational aids. As additional sources of reference, the appendixes include a bibliography and summaries of all papers appearing in volume I of the set.

SCIENCE AT WAR. By J. G. Crowther and R. Whiddington. Philosophical Library, 15 East 40 Street, New York, N. Y., 1948. 185 pages, illustrations, diagrams, maps, $8^{3}/_{4}$ by $5^{1}/_{2}$ inches, cloth, \$6. Written for the layman as well as the scientist, this book presents an authoritative account of some of the more important aspects of the scientific contribution to the war effort. It is based on the official archives and documents assembled by the Scientific Advisory Committee to the British Cabinet. Among the basic topics dealt with are: radar, the atomic bomb, operational research, and science at sea.

STANDARD HANDBOOK FOR ELECTRICAL ENGINEERS. Edited by A. E. Knowlton. Eighth edition. McGraw-Hill Book Company, New York, N. Y., Toronto, Ontario, Canada, London, England, 1949. 2,311 pages, diagrams, charts, tables, $9^{1}/_{4}$ by 6 inches, leather, \$12. A handy-reference compilation of practical data from all fields of electrical engineering, plus the most frequently required fundamental theory, units, and systems of measurement. The new edition contains material on developments in the field since the previous edition of 1941.

SYMPOSIUM ON SEARCHLIGHTS. Illuminating Engineering Society, 32 Victoria St., London, S. W. 1, England, 1948. 164 pages, illustrations, diagrams, charts, tables, $9^{3}/_{4}$ by 6 inches, paper, 17s.6d. This pamphlet contains five papers on searchlight characteristics and design and visibility problems with the discussion, as presented at the April 15, 1947, meeting of the society. A further paper on aircraft searchlights for antisubmarine warfare is included.

SYMPOSIUM ON SPECTROSCOPIC LIGHT SOURCES. 49th Annual Meeting, Buffalo, N. Y., June 24–28, 1946, (Special Technical Publication 76), American Society for Testing Materials, 1916 Race Street, Philadelphia, Pa., 1948. 79 pages, illustrations, diagrams, charts, tables, 9 by 6 inches, paper, \$2. The symposium discusses the field of spectrochemical analysis which is concerned with the excitation of the sample. The first paper summarizes present practice and correlates it with the more detailed studies to follow. Succeeding papers present a detailed study of the controlled spectrographic spark source; spectrographic sources from the viewpoint of the physicist; and results of a study of various processes occurring in the discharge.

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TRAINING EMPLOYEES AND MANAGERS. By E. G. Planty, W. S. McCord, and C. A. Efferson. Ronald Press Company, New York, N. Y., 1948. 278 pages, illustrations, diagrams, tables, $9^{1}/_{4}$ by 6 inches, cloth, \$5. Provides those engaged in industrial training work and those who wish to enter the field with a useful guide. The scope, objectives, and techniques of the training now being practiced by companies are set forth. Part I introduces the broad concepts which have been developed in recent years in the field of business and industrial training. Part II deals with the organization and administration of training. Part III is devoted to training programs and methods.

VACUUM MANIPULATION OF VOLATILE COMPOUNDS. By R. T. Sanderson. John Wiley and Sons, New York, N. Y.; Chapman and Hall, Ltd., London, England, 1948. 162 pages, diagrams, tables, $8^{1}/_{2}$ by $5^{1}/_{2}$ inches, cloth, \$3. Of interest particularly to the investigator without special training in the field, this book provides a firm foundation for working with high-vacuum apparatus. It supplies all the data necessary for the construction and operation of such apparatus. The appendix includes reference material on instruments used in this type of research and on almost 400 compounds conveniently studied by the described procedures.

VANDERBILT RUBBER HANDBOOK. Edited by S. S. Rogers. Published by R. T. Vanderbilt Company, 230 Park Avenue, New York, N. Y. Ninth edition, 1948. 719 pages, illustrations, diagrams, charts tables, $8^{1}/_{2}$ by $5^{1}/_{2}$ inches, fabrikoid, \$7.50. The purpose of this reference manual is to instruct new men entering the rubber industry in the fundamentals of compounding, and to provide experienced technologists with needed information and data. To accomplish these aims, the discussion deals first with basic substances, properties and processes; next with fundamental compounding procedures; and finally with the application of the foregoing principles to the compounding of specific types of rubber goods.

WAVE MECHANICS AND ITS APPLICATIONS. By N. F. Mott and I. N. Sneddon. Oxford University Press, New York, N. Y.; Clarendon Press, Oxford, England, 1948. 393 pages, diagrams, charts, tables, $9^{3}/_{4}$ by 6 inches, cloth, \$10. Intended for the student of physics or chemistry who wishes to use quantum mechanics. No attempt is made to present fundamentals in their most general form. Schrödinger's wave equation for a single particle in an electrostatic field and the generalized form of the equation are considered, and chapters are devoted to applications to atomic and molecular structure, radiation, and collision problems, and the properties of solids.

WELDING FUNDAMENTALS. By H. P. Rigsby. Pitman Publishing Corporation, New York, N. Y., and London, England, 1948. 178 pages, illustrations, diagrams, charts, tables, $9^{1}/_{4}$ by 6 inches, cloth, \$2.75. In this compilation of the fundamentals and principles of welding for the engineering student the actual technique of welding is treated as secondary material. Following a historical development of the various welding methods, are chapters on the equipment needed for each method. Welding gases, rods, fluxes, and types of joints are considered as well as the testing of welds. Standard welding symbols and a glossary of welding terms are included.

PAMPHLETS • • • • •

The following recently issued pamphlets may be of interest to readers of "Electrical Engineering." All inquiries should be addressed to the issuers.

Possibilities for Heat Pump Expansion. Discusses future outlook with reference to application, heat and energy sources, types of systems, cycle, and distribution. Available at ten cents per copy from V. W. Palen, Bureau of Public Information, New York University, Washington Square, New York 3, N. Y.

Two Reports on German Management. PB 32567, "Investigation of Production Control and Organization in German Factories," is a 14-page booklet selling for 50 cents. Comprising 40 pages and priced at \$1 is PB 78263, "Training and Selection of Supervisory Personnel in the I. G. Farbenwerke, Ludwigshafen." Address orders to the Office of Technical Services, Department of Commerce, Washington 25, D. C.

Symposium on Usefulness and Limitations of Samples. A 40-page booklet containing three papers: "Sampling and Its Uncertainties;" "On Variations in Materials, Testing, and Sample Sizes;" and "The Amount of Inspection as a Function of Control of Quantity." Priced at \$1. May be procured from American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa.

An Ocean Wave Measuring Instrument. Technical Memorandum Number 6. Describes a surface-mounted wave gauge for measuring height and period characteristics of water surface variations due to wave action. Includes 28 pages of text plus illustrations. Available upon request from President, Beach Erosion Board, Corps of Engineers, 5201 Little Falls Road N. W., Washington 16, D. C.

Bulletin of the Beach Erosion Board. Volume 3, Number 6. Contents are: a paper which develops a formula for the calculation of rock-fill dikes; a listing of beach erosion studies now in progress; and a listing of recent beach erosion literature. A 35-page booklet put out by the Beach Erosion Board, Washington 16, D. C.

An Experimental Study of Submarine Sand Bars. Technical Report Number 3. Discusses characteristics of, and factors affecting, bar formation. Results of laboratory experiments and observational data are given. Available on request from the Beach Erosion Board, Corps of Engineers, 5201 Little Falls Road N. W., Washington 16, D. C.

Tempil Topics. Volume 4, Number 1. Brief summary of basic metallurgical data on copper and its alloys. Copies on request from the Tempil Corporation, 132 West 22d Street, New York 11, N. Y.